MARYLAND WEATHER SERVICE

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VOLUME ONE

MARYLAND

WEATHER SERVICE

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BALTIMORE
THE JOHNS HOPKINS PRESS
1899

The Marine Service.

The Lord Baltimore Press
ΙΩΤΑ ΕΝ ΟΥ ΜΗ ΠΑΡΕΛΘΗ
The Friedenwald Company
BALTIMORE, MD., U. S. A.

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The Maryland Weather Service is conducted under the joint auspices of the institutions above mentioned, the Central Office being located at the Johns Hopkins University. The meteorological work is under the immediate supervision of the Meteorologist who is detailed by the Chief of the U. S. Weather Bureau. He is assisted by voluntary observers scattered throughout the twenty-three counties of the state, who report regularly to him. Other lines of investigation are carried on in co-operation with various State and National organizations.

LETTER OF TRANSMITTAL

To His Excellency, Lloyd Lowndes,
Governor of Maryland.

Sir:—I have the honor to present herewith the first volume of the new series of reports of the Maryland Weather Service. The Board of Control plan to publish in the near future a full account of the climatic features of Maryland, in which the physiography, the meteorology, the hydrography, the medical climatology, the agricultural soils, the forestry, the crop conditions, and the flora and fauna of the state will be considered. The present volume is confined to a discussion of the physiography and meteorology. I am,

Very respectfully,
William Bullock Clark,
Director.

Johns Hopkins University,
July 1, 1899.

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PREFACE

The present volume is the first of a series of reports dealing with the climatic features of Maryland. Much work has already been done in the preparation of the subsequent volumes and they will follow from time to time as the investigations are completed.

Attention should be called at the opening of this first volume to the extensive aid that has been rendered the State Service since its organization by the various National Bureaus. Professor Willis L. Moore, Chief of the U. S. Weather Bureau, has largely assisted the meteorological investigations, which for several years constituted the main work of the Maryland Weather Service. Not only have valuable assistants been detailed to the central office in Baltimore, but instruments and forms have been liberally supplied for the conduct of the work. Hon. Charles D. Walcott, Director of the U. S. Geological Survey, has also greatly facilitated the topographic and hydrographic surveying of the state, furnishing the greater part of the men and means for carrying on the work along both these lines. Much support has also been obtained for the more strictly agricultural investigations from the various scientific divisions of the U. S. Department of Agriculture, particularly through Professor Milton Whitney, Chief of the Division of Soils, who also represents the Maryland Agricultural College as a member of the Board of Control.

The Johns Hopkins University and the Maryland Agricultural College, which are directly connected with the management of the State Weather Service, as well as the Maryland Agricultural Experiment Station and State Horticultural Bureau, are closely identified with the various lines of investigation pursued by the Service, and

their support has been of much aid in the furtherance of the plans for the present series of reports.

The Maryland Geological Survey, especially, is conducted in such active co-operation with the Maryland Weather Service that each bureau has largely benefited from the work of the other. This arrangement has been and will continue to be of great importance in the investigation of the natural resources of the state and will become more and more appreciated as subsequent reports are published.

The *Introduction* to the present volume, prepared by Wm. Bullock Clark, and constituting Part I, is devoted mainly to a discussion of the plan of operation of the Maryland Weather Service, together with a recital of the facts connected with its organization. A history is given of the work and publications of the Service since May, 1891, when the bureau was established, as well as the scope of the proposed publications.

The chapter on the *Physiography of Maryland*, which forms Part II of the volume, has been prepared by Cleveland Abbe, Jr., and embraces a general statement regarding the more important physiographic features of the state. To this is appended a detailed discussion of stream development in the Piedmont Plateau.

The report on the *Meteorology of Maryland*, which comprises Part III of the volume, is the joint work of Cleveland Abbe, F. J. Walz, and O. L. Fassig, all of whom are members of the staff of the U. S. Weather Bureau.

Professor Abbe, of the U. S. Weather Bureau, whose distinguished position in the science of meteorology has been long recognized both in this country and abroad, has prepared the first chapter of this report on the Aims and Methods of Meteorology. This valuable contribution will have much interest for those who are desirous of acquainting themselves with meteorological phenomena.

The succeeding chapters, relating especially to Maryland meteorology, are prepared by Messrs. Walz and Fassig of the Baltimore office of the U. S. Weather Bureau, the former being the Local Forecast Official and Section Director of that Bureau as well as Meteorologist of the State Weather Service, while the latter, in addition to being a Section Director of the U. S. Weather Bureau, is also Instructor in Meteorology in the Johns Hopkins University. The chapter by Dr. Fassig, which follows that of Professor Abbe, deals with the history of the development of knowledge regarding Maryland meteorology from early colonial times to the present. The final chapter by Mr. Walz is an exhaustive study of Maryland meteorology, based upon the records of past years. This work has required the critical examination of a vast amount of recorded data in which all the members of the Baltimore office have been engaged. Mr. Walz has been especially aided in this work by Mr. E. C. Easton of his staff.

The illustrations employed in this volume have been obtained from many different sources. The Maryland Weather Service desires especially to thank the various railroad companies of the state for their kindness in liberally supplying such illustrations of scenery as were desired. The aid rendered by the Baltimore and Ohio, Pennsylvania, Western Maryland, and Cumberland Valley Railroads deserves especial mention.

The U. S. Weather Bureau has generously allowed the use of its drawings in illustrating various types of weather and has furnished special prints and transfers from its plates. Several of the illustrations used by Professor Abbe and Mr. Walz have been secured from this source.

The Hydrographic Office of the Navy Department has kindly permitted the reproduction of the beautiful cloud plates which were published two years ago for its observers. They add much to the effectiveness of the discussion of cloud types by Professor Abbe.

The U. S. Geological Survey, by kindly permitting the use of transfers from several of its topographic atlas sheets, has made it possible to illustrate upon a proper base the leading types of Maryland topography. They also furnished photographs of many of the instruments illustrated in the volume.

Several valuable plates have been secured through the kindness of the publishing firms of Harper Brothers and the American Book Company which aid in illustrating certain important points in Maryland physiography. Other illustrations of value have been secured through the kindness of private individuals, especially of Dr. Harry Fielding Reid, Mr. A. B. Hoen, Dr. Edward B. Mathews, and Mr. A. Bibbins.

Dr. E. B. Mathews, the Assistant State Geologist, has rendered most efficient service in the publication of the present volume, by the aid he has given in editing the manuscripts presented, and in supervising their passage through the press.

PART I

INTRODUCTION

ESTABLISHMENT AND PLAN OF OPERATION OF THE SERVICE

BY

WM. BULLOCK CLARK

THE HELIOTYPE PRINTING CO. BOSTON

THE ROCKS OF DEER CREEK.

ON THE BALTIMORE & LEHIGH RAILWAY.

INTRODUCTION

ESTABLISHMENT AND PLAN OF OPERATION OF THE SERVICE

BY

WM. BULLOCK CLARK

ESTABLISHMENT OF THE SERVICE.

The variety in climatic conditions found represented within the limits of Maryland is no less striking than that shown in the diversified physiography, geology and mineral wealth of the state elsewhere described, and has influenced in no less pronounced degree the development of the social and commercial life of the people. From the eastern to the western borders of Maryland may be found a succession of districts suitable from their climatic characteristics for the most diverse employments; indeed, there are few areas of equal size in which such striking differences appear. Although these facts were early recognized in a general way, it was not until the present organization was established that any systematic attempt was made at their investigation.

The practical significance of climatic study is to-day recognized by all governments, State and National, and nearly every one, both in this country as well as abroad, makes provision for its maintenance. Both from an economic and an educational standpoint it has been found to be of such value to the people that there is a growing appreciation in all quarters of its importance. To Maryland, especially, with its lowlands and highlands, its ocean front and included estuaries, a complete knowledge of the climate must be of much practical value. Not only is this information of importance from the standpoint of personal comfort, and thus of interest to those who now abide within the state or who contemplate residence among us, but the character

of the climate likewise affects the soil conditions, the distribution of plant and animal life, the water-supply and the drainage, and therefore the general health of every community in the state. All of these factors, which are so intimately connected with the climate, must be regarded as within the province of a weather service, and it was with the purpose of investigating them that the present organization was established.

The Maryland State Weather Service was provisionally organized in May, 1891, under the joint auspices of the Johns Hopkins University, the Maryland Agricultural College and the U. S. Weather Bureau. The few scattered observers in Maryland and Delaware who had, prior to that time, reported to the Chief of the U. S. Weather Bureau, or rather Chief of the U. S. Signal Service[1] as he was then called, were authorized on that date to send their subsequent reports to the central office of the new bureau at the Johns Hopkins University; at the same time the Baltimore office of the U. S. Weather Bureau was moved to the University, as the efficiency of the State Service was recognized to depend to a large extent on the closeness of co-operation with the National Service. Quarters were assigned in the Physical Laboratory of the University, and the roof of that building was subsequently used for several years for the exposure of the instruments on which the records of the bureau were based.

Two series of reports were at once established, a monthly Meteorological Report and a weekly Crop Bulletin. These reports were sent widely throughout the state and elicited much favorable comment from the people and the press.

It was evident from the start that the results of the Maryland State Weather Service could not be made as generally available to the people at large as was desirable, unless the state itself provided means for the publication and distribution of the information obtained. The institutions interested in the organization of the State Service, and the many voluntary observers throughout the state who

[1] The meteorological work of the country was conducted by the U. S. Signal Service of the War Department until July 1, 1891, when it was transferred to the Department of Agriculture and the U. S. Weather Bureau formed. The actual work of the State Service did not begin until the organization of the latter bureau.

participated in the work, were willing to furnish and prepare the data for publication, but no fund could be permanently relied upon for the printing and distribution of the reports.

The Bill.

In order that official recognition might be secured for the Service, and a sufficient fund obtained to meet the expenses of publication, a bill was introduced in the General Assembly upon February 5, 1892, was passed by the Senate upon March 25, by the House upon March 31, and received the signature of the Governor upon April 7. The bill under which the Service was established reads as follows:

"An Act to establish a State Weather Service, and to make an Appropriation therefor."[1]

Section 1. *Be it enacted by the General Assembly of Maryland,* That there is hereby established a State Weather Service, which shall be under the control and management of the Johns Hopkins University, the Maryland Agricultural College and the United States Weather Bureau. The officers of said service shall be a Director, designated by the President of the Johns Hopkins University, a Secretary and Treasurer, designated by the President of the Maryland Agricultural College, and a Meteorologist in charge, designated by the Chief of the United States Weather Bureau; they shall be commissioned by the Governor, and be duly qualified as officers of the State. The said officers shall constitute a Board of Government, under the direction of the institutions from which they are appointed, and shall receive no compensation for their services as such officers.

Sec. 2. The central station and office of said service shall be at the Johns Hopkins University. The Board of Government shall establish, if practicable, one or more voluntary meteorological stations in each county of the State, and supervise the same, co-operating with the Chief of the United States Weather Bureau for the suitable location of such stations, in order that the greatest usefulness may result to the State and National services. The said officers are authorized to print weekly and monthly reports of the results and operations

[1] Laws of Maryland, 1892, Chapter 329.

of said services, and to distribute the same in such manner as they shall deem most serviceable to the people of the State.

SEC. 3. The sum of two thousand dollars annually, or so much thereof as shall be necessary, is hereby appropriated out of any funds of the Treasury not otherwise appropriated, for the purpose of carrying out the provisions of this Act, to be paid to said officers, or to their order, by the Treasurer, upon the warrant of the Comptroller, and upon the vouchers of said officers; provided, however, that no part of said sum shall be paid for salaries for any officer or officers, but a reasonable compensation may be paid for printing and other necessary and proper expenses of said officers.

SEC. 4. The said officers shall report to the Legislature at its regular sessions their expenditures under the provisions of this Act, and such other information as said officers may deem desirable, or as the Legislature may require.

SEC. 5. *And be it further enacted,* That this Act shall take effect from the date of its passage.

OFFICERS OF THE SERVICE.

The officers of the Board of Government, nominated shortly after the passage of the bill by the heads of the three institutions under whose control the Service was placed, and who were subsequently commissioned by the Governor, were Wm. Bullock Clark, Director, representing the Johns Hopkins University; Milton Whitney, Secretary and Treasurer, representing the Maryland Agricultural College; and Corydon P. Cronk, Meteorologist in charge, representing the U. S. Weather Bureau. The first two members of the Board have continued in their positions since the organization of the Service, but the representative of the U. S. Weather Bureau has been twice changed, the present incumbent being F. J. Walz, the Local Forecast Official stationed in Baltimore.

LINES OF INVESTIGATION PURSUED BY THE SERVICE.

The objects for which the Maryland State Weather Service was organized embrace a thorough study of all the varied climatic conditions of the state, together with their influence upon the welfare of the people.

The science of climatology, when viewed in its broader aspects, includes not only meteorological phenomena and the causes which produce them, but also those conditions of the earth's crust which are dependent upon atmospheric influences. Thus the investigation of the temperature and moisture of the soil, and of the conditions of plant growth, are questions equally within the province of the student of climate as the determination of the pressure or temperature of the atmosphere.

The climate of a particular district is furthermore determined by so many factors of a general and specific nature that the consideration of many topics, apparently more or less remote from what we commonly regard as climate, must be undertaken. Thus, for example, we must understand the topographic and physiographic features of the region if we would rightly interpret its climate, but in order to comprehend these features properly a knowledge of geology is necessary.

Then, too, a whole train of consequences follows upon the climate—the disposition of the rainfall influencing water-supply and water-power, the salubriousness of the country affecting health, the soil conditions and their influence on crops, the character of forest growth, the distribution of plant and animal life, not to mention the profound effect which these have, both directly and indirectly, upon the commercial and social welfare of the people; in short, there are no problems so intimately associated with the well-being of a community as those of climate.

In the succeeding pages these various factors will be considered under the heads of topography, physiography, meteorology, hydrography, medical climatology, agricultural soils, forestry, crop conditions, flora and fauna.

Topography.

A knowledge of the topography of a country is no less essential to the interpretation of its climate than to that of its geology, and as legitimately forms part of a climatological study of a district as of a geological investigation. The Maryland State Weather Service, like the Maryland Geological Survey, has been actively engaged in a

plan of co-operation with the U. S. Geological Survey for the completion of the topographic map of the state.

The state of Maryland very early recognized the importance of topographic work, and already in 1833 the General Assembly took action in the matter. The map which was subsequently made under the direction of Mr. J. H. Alexander, Topographical Engineer, was the most complete map of so large an area that had been undertaken anywhere in the country, and served as a base for many purposes in subsequent years.

Little further knowledge was gained regarding the topography of the state until after the organization of the U. S. Geological Survey, when in 1883 topographic work was commenced within the limits of the state of Maryland. The National Survey has been engaged in topographic work in different portions of the country for nearly twenty years, but on account of the great areas which it has to cover, and the necessary division of its work among the several states, is able to do but a small amount in each annually, unless the state itself co-operates or through its scientific activity shows the necessity for increased attention.

During the period since 1883 the U. S. Geological Survey has already done considerable work within the limits of Maryland, but it was not until the organization of its scientific bureaus, which showed the necessity of an early completion of the mapping that Maryland has secured adequate attention in this regard. This work has been pushed with much vigor during the past two years, since the organization of the Maryland Geological Survey. It was felt, however, that the state could not continue to receive so large an amount of aid in this work unless more extensive co-operation was assured by Maryland, as in the case of many of the other states. With this object in view a bill was introduced at the last session of the General Assembly calling for an appropriation of $5000 annually, to be used in the completion of the topographic survey of the state. This bill was passed on March 17th of last year and the fund provided was thus available for the past field season. Prior to this a small amount had been set apart annually by both the Maryland Geological Survey

and the State Weather Service for the purpose of co-operation with the U. S. Geological Survey in the preparation of topographic maps, but it was wholly inadequate for the completion of the work in a reasonable time.

The co-operation thus effected between the State and the National Governments will secure the completion within a few years of an accurate topographic base map of Maryland. This map will be of great benefit to the people of the state for all engineering purposes, and will be an important aid in the location of railroads, highways, water conduits, drainage systems and other internal improvements. From the fact that these maps accurately show the relief of the surface they will likewise prove of much value to the agricultural, industrial, and military interests of the state. Moreover, they are absolutely essential for the proper conduct of the scientific and economic surveys of the state which are now in progress.

The topographic map will ultimately be published, both in rectangular sheets of constant size and by counties upon scales of one mile and two miles to the inch, and upon this base will be platted not only the elevations, streams, roads, etc., but also the distribution of the various natural resources of the state. They will find place from time to time, not only in the publications of the Maryland Geological Survey, but of the Maryland Weather Service.

Physiography.

It is important that the physiographic characteristics of the state should be systematically investigated and the origin and distribution of our mountains, valleys and plains determined. These factors, which are so intimately connected with the geology, have a marked bearing upon the climate as well. It is impossible to fully comprehend our climatic conditions without a knowledge of the distribution of our land and water areas, of the location and elevation of our mountains and of the extent and position of our plains. Such investigations of the natural physiographic features of the state have a very practical significance to the inhabitants of Maryland and for those who are considering residence amongst us. The educational significance of such knowledge should also not be ignored, and a means

so valuable for training the powers of observation should be brought to the attention of the teachers in our schools and colleges. Such investigations have been carried on in connection with the scientific bureaus of the state, and already much valuable information has been obtained. It is intended that this information shall be presented in a thoroughly systematic and detailed manner, accompanied by such graphic illustrations as will clearly bring to the minds of the public the varied physiography of Maryland.

METEOROLOGY.

The subject of meteorology is to the public mind largely regarded as the equivalent of climatology, and yet its province is confined to atmospheric conditions, and thus constitutes only a part of the much broader field of climatology. No questions of greater importance to the welfare of the community present themselves for study, however, than those of meteorology, as there is nothing which more influences the character and occupation of the people than temperature and rainfall. Not only the extremes of heat and cold, of moisture and dryness, but the average distribution of these conditions throughout the year must be considered, since their character in this regard is of the utmost importance.

No subject earlier attracted the attention of the people of Maryland than that of climate, and in the records of the first settlements many accounts of the meteorological conditions are found. Subsequently, more careful data were collected, and during the present century, especially, tables of temperature and rainfall have been frequently prepared and published by private observers. After the organization of the National Weather Service, little more than a quarter of a century ago, volunteer observers were obtained in various sections of the state, whose records have been carefully preserved, but it was not, as above described, until the organization of the Maryland Weather Service in 1891 that thoroughly systematic observations were undertaken throughout the state. It is the intention of the local Service, by co-operation with the U. S. Weather Bureau, to still further extend this work to all the districts of the state until complete records shall be obtained of the meteorological conditions of

every county. Many special subjects, as for example, the influence of the Chesapeake Bay and of the higher mountains of Western Maryland upon temperature and rainfall, will be investigated. It is believed that a knowledge of these and other factors will be of much practical value to the various material interests of the state.

Hydrography.

The rainfall upon the surface of the land is variously disposed of, a part following the valleys directly to the sea, a part percolating through underground channels, a part being removed by evaporation, and a part being taken up by chemical changes in the earth's crust. In different areas these various factors have widely different values, dependent both upon the character of the rainfall and upon the physical conditions of the drainage basins. They further determine the amount of available water-power and water-supply in all portions of the state. The hydrographic conditions in Maryland thus become of great importance, not only to the agricultural and manufacturing interests of the state, but to every citizen of the commonwealth.

Modern methods of investigation have shown the utility of carefully collecting all available data upon this subject, not only as regards the outflow of the streams at various points and at different seasons of the year, but also as regards the physical conditions of the drainage basins themselves.

It is the intention of the Maryland Weather Service to fully investigate this subject in its various aspects. Already much work has been done in co-operation with the Hydrographic Division of the U. S. Geological Survey in the study of several of the drainage basins, while many measurements have been made of the run-off of the leading streams. An early publication of these results is proposed.

Medical Climatology.

The healthfulness of Maryland as a place of residence is a question of no small importance to those who may be considering the advisability of seeking homes in our midst, and actual facts should be presented in such a manner as to command their attention. The

various sections of the state, with their marked differences in temperature and rainfall, may be shown to be adapted to the physical requirements of different people, and it is highly important that these facts should be made known.

It is also probable, as the meteorological records over considerable periods are carefully studied, that some districts will be found highly beneficial to people suffering from certain ailments. It is the purpose of the Maryland Weather Service to have some expert upon medical climatology carefully study its records and prepare a report upon this subject, and already arrangements to this end have been perfected.

Agricultural Soils.

The effects of temperature and rainfall are nowhere more profound than upon the surface rocks of the earth's crust. These become, when consolidated, gradually broken down by atmospheric and other agencies into minute fragments, which, mingled with decaying organic matter, afford the agricultural soils. The influence of meteorological conditions is always present in soils, and soil temperature and soil moisture are recognized as highly important factors in plant growth. No question which will be considered by the Maryland Weather Service and the Maryland Geological Survey is of greater practical significance to our agricultural interests.

It is the purpose of the Maryland Weather Service and Maryland Geological Survey, in co-operation with the State Agricultural Institutions, to make a thorough investigation of this important subject under the direction of Professor Whitney, who can also bring to the aid of the work the facilities of the U. S. Department of Agriculture, with which he is connected.

The classification of the soils will be primarily based upon the lithological character of the several geological formations, since each formation has been recognized to produce its own peculiar soils, fitted for certain definite crops. The physical and chemical characteristics of these various soils will be further examined along the lines which have been so successfully elaborated by Professor Whitney and his co-workers. The State Weather Service feels confident that large returns must result from these investigations.

THE HELIOTYPE PRINTING CO. BOSTON

CALVERT CLIFFS, ON THE CHESAPEAKE BAY.

Forestry.

The character and distribution of the forest growth of Maryland are mainly determined by the various climatological factors which have already been described. At the present time very little information is obtainable regarding the forests of the state, and a study of this question cannot fail to result in much practical benefit to the various agricultural and commercial interests of Maryland. It is not only important to classify our present available timber, so that information may be given to those who are seeking such knowledge, but it is also of value to indicate what types of forest growth are best suited to particular soils. Much valuable work has been done in the way of forestry surveys in recent years, and it is the intention of the State Weather Service to follow out similar lines of work in Maryland with such aid as it can secure from experts in this field of investigation. The active support of the Forestry Divisions of the U. S. Geological Survey and of the U. S. Department of Agriculture is already assured in the work.

Crop Conditions.

The study of the climatology of the state leads naturally to a consideration of its crop conditions, which more largely affect the agricultural interests of the state than any other single subject. The important work which the State Agricultural Institutions have been engaged in conducting during many years past renders it possible for them to aid largely in the preparation of a general report upon this subject. The President of the Agricultural College has consented to supervise the publication of a statement that will show the relations that exist between Maryland crops and the climatic influences active within the state. Such a report when prepared will be of great practical value to our agricultural interests.

Flora and Fauna.

Comparatively little work had been done in systematically studying the distribution of plant and animal life within the limits of the state of Maryland until the organization of such investigations a year ago by the State Geological Survey and State Weather Service.

Individuals, at various times and in different parts of the state, have collected local data which will be of much value in the proposed study, when the results have been carefully collated. The State Horticultural Bureau also plans to organize work along these lines, particularly among the lower organisms, and it has been arranged that the State Geological Survey and State Weather Service shall combine with that bureau in conducting investigations in this field. The scope of the work is necessarily so great, due to the lack of any kind of biological survey in the past, that several years must elapse before anything like complete results can be secured.

It is the purpose of the Maryland Weather Service and Maryland Geological Survey, in co-operation with the State Horticultural Bureau, to prepare complete systematic reports upon the flora and fauna of the state, in which the relation of plant and animal distribution to geological and climatological conditions will constitute an important feature since it is believed that results of this kind will prove to be not only of economic but educational value to the people of the state. The active co-operation of the Biological Survey of the U. S. Department of Agriculture is also assured in these investigations so that the citizens of Maryland may confidently expect in a few years a report of more than usual value on this subject.

PUBLICATIONS.

The Maryland Weather Service has published reports from time to time containing information in regard to the climate of the state, which have been widely distributed throughout this country and abroad. These official publications have elicited much favorable comment on the part of scientific and commercial journals, and it is believed that they have been of value in spreading far and wide a knowledge of the climate that must ultimately result in great advantage to the state.

The publications of the Maryland Weather Service may be classed under three heads: first, those which were published prior to the official organization of the Service in 1892; second, those which were published after the passage of the bill by the General Assembly in

1892 until 1896; and third, those which have been published since 1896 in co-operation with the U. S. Weather Bureau as reports of the Climate and Crop Service.

First. The Maryland Weather Service as an unofficial organization published seven small monthly Meteorological Reports between May and November, 1891, which constitute Volume I of its monthly publications. Short weekly Crop Bulletins were also issued between June 26th and September 25th of the same year. All of these reports were sent widely throughout the state and to distant points.

Second. After the official organization of the Maryland Weather Service by the General Assembly in 1892, the publication of the monthly Meteorological Reports in an enlarged form was at once inaugurated, and was continued without interruption from April of that year until August, 1896. They constitute Volumes II to VI of the monthly reports. Throughout the same period Crop Bulletins were published weekly during the growing and harvesting seasons. Two Biennial Reports were also prepared for the General Assembly of 1894 and of 1896, in which the results of the observations, secured by the observers of the Service and tabulated in the monthly reports, were carefully compiled and presented in a readable form, accompanied by diagrams and maps. These reports were widely distributed both in this country and abroad. During 1893 a series of large Climatic Charts was prepared to show the average annual and seasonal temperature and rainfall of the state. These charts were placed on exhibition at the World's Fair in Chicago and subsequently distributed. They presented in a graphic manner the leading characteristics of Maryland climate.

Third. During 1896 a plan of closer co-operation between the National and State Bureaus was proposed by Professor Willis L. Moore, Chief of the U. S. Weather Bureau, as a result of which the Climate and Crop Service of that organization now assumes largely the expense and responsibility for the publication of the general meteorological data secured from the volunteer observers of the State Service throughout Maryland. This change has been found to be mutually beneficial to both organizations.

It is the plan of the Maryland Weather Service to devote its energies in the future chiefly to the publication of special reports on the climatology of the state, as it is believed that such reports will prove of even greater value to the people of Maryland. The investigations connected with this work, begun in 1896, have been continued during the last two years with important results, and already several articles of value have been prepared. During this period the State Service has continued to co-operate with the National Bureau in the accumulation of the general meteorological data and in the publication of the monthly and weekly reports, so that the earlier work and associations are still, in a measure, maintained. The publication of the present volume fully inaugurates the third and most important period in the history of the Service.

PART II

A

GENERAL REPORT

ON THE

PHYSIOGRAPHY OF MARYLAND

BY

CLEVELAND ABBE, Jr.

A GENERAL REPORT
ON THE
PHYSIOGRAPHY OF MARYLAND

Physiographic Processes.

INTRODUCTION.

From the earliest times men have observed more or less closely the various phenomena which nature presents, and have sought to find an explanation for them. Among the most interesting of these phenomena have been those which bear on the development of the surface features of the earth or its topography. Impressed by the size and grandeur of the mountains, their jagged crests and scarred sides, early students of geographical features were prone to ascribe their origin to great convulsions of the earth's crust, earthquakes and volcanic eruptions.

One generation after another comes and goes, yet the mountains continue to rear their heads to the same heights, the rivers to run down the mountain sides in the same courses and follow the same valleys to the sea. So men came to look upon the mountains as permanent after they were upheaved, and adopted them as symbols of eternity and unchangeableness. How often to-day, even, do we hear expressions such as "the everlasting hills," and "firm as a rock." With such conceptions concerning the origin of mountains and their duration went the related ideas that the rivers found valleys ready made for them in the shape of cracks and chasms in the earth, formed during the birth of the mountain ranges. Those who held these views thus saw no relations whatever between the mountains and the rains which fell upon them, between the rivers and the shaping of the valleys which held them. They believed the mountains

existed first and that the rains, snows, glaciers and rivers came afterwards.

Other men recognized in the waters flowing through the valleys a powerful agent by means of which the gorges, canyons, and broader valleys had been carved out. This carving, however, they believed to have been done in some long past period, when a great volume of water swept down the river courses, tearing away rocks and trees and fashioning the valley; or they held that all the lands of the earth were at one time submerged by the ocean, and that great currents, flowing in the seas of that period, carved out the river valleys which we see to-day. Those who held such views are now called the Catastrophists, because they appealed to great convulsions, catastrophes and cataclysms to explain the various geological and geographical phenomena which they saw about them.

Upholders of the cataclysmic theories concerning the origin of the earth's features were numerous and even in the majority as late as the beginning of the present century, yet a few individual thinkers had centuries before held different and what are now believed to be truer ideas concerning geological phenomena. Among the early forerunners of the present school were Aristotle and Strabo. Aristotle opposed the catastrophic teachings, saying that "the changes of the earth are so slow in comparison to the duration of our lives, that they are overlooked."[1] Strabo also maintained that the features of the land and sea were to be explained by the operation of natural processes during past ages.

Thus early were foreshadowed the conclusions which Hutton pronounced as the result of his studies in the fields and on the shores of Great Britain. These conclusions are briefly summarized in the following statement given by Playfair:[2] "Amid all the revolutions of the globe the economy of Nature has been uniform, and her laws are the only things that have resisted the general movement. The rivers and the rocks, the seas and the continents, have been changed in all their parts; but the laws which direct those changes, and the rules to which they are subject, have remained invariably the same."

[1] See Lyell, "Principles," 1873. p. 21, quoted from "De Die Natura."
[2] Playfair, "Illustrations of the Huttonian Theory." p. 374.

In this passage is the key to the principles which have guided the modern study of geology and geography. Since the year 1785, in which Hutton published his "Preliminary Sketch of the Theory of the Earth," the student of the Earth Sciences has been guided more and more by the principle that the Past is to be interpreted in the light of the Present.

To-day we recognize that the greater number of the valleys have been carved in the landmasses by the everlasting and continuous action of the weather in breaking up the rocks and of the rivers in carrying these broken rocks away. We do not regard the earth's features as the products of convulsions or catastrophes such as deluges or holocausts, but as resulting from the interaction of two sets of agencies, slow in performance but powerful and all-pervading. One set of agents continually strive to build up the land above the seas, and these we call agents of construction; the other set of agents as constantly and persistently strive to tear down or destroy the work performed by the first class, and to this set we give the name of destructional agents or agents of denudation. We have, then, to consider two great classes, the agents and processes of construction and the agents and processes of destruction or denudation.

PROCESSES OF DENUDATION.[1]

The agents of denudation are all the time actively carrying on their work about us. Indeed, most of them are perfectly familiar to us and frequently attract our attention, but we rarely or never stop to think what they mean, what relation they bear to the surface forms of the earth, or even what influences they exert upon us. It will be profitable then to consider briefly these agents and their methods of work.

For convenience of treatment, the different agents and their proper processes may be grouped into three general classes, viz. *Atmospheric*, or those agents and processes which are peculiar to the atmosphere as we commonly regard it; *Aqueous* or hydrous, or the action of

[1] The main facts and principles of rock-weathering as explained in the sequel, are taken from G. P. Merrill's "Rocks, Rock-Weathering and Soils." 1897. pp. 172, et seq.

moisture and water after it has left the atmosphere; *Organic* agents and processes, whose effectiveness is due to the direct or indirect intervention of members of the Animal or Vegetable kingdoms.

Atmospheric Processes.

The direct chemical activity of the atmosphere in breaking down the rocks is not very great. The atmosphere contains, in addition to its essential constituents nitrogen (4/5) and oxygen (1/5), very appreciable quantities of a number of gases such as carbonic acid gas, nitric acid gas, and ammonia, which, when in combination or aided by moisture, are very effective agents of rock disintegration and decay, but when in the dry state as parts of the atmosphere, possess but little chemical power. It is therefore the water vapor in the atmosphere which plays the most important part in the atmospheric processes. This will be treated of separately and need not be further noticed here since it becomes most effective after collecting as rain.

The mechanical processes of the atmosphere are of more direct influence. Districts which are subject to an extreme daily range in temperature, as the peaks of high mountain ranges, most tropical countries and many continental interiors, present many striking illustrations of the way in which rapid alternations of expansion and contraction cause rocks to break up. After a long day, during which the sun pours down its heat upon the exposed ledges and raises them at times to temperatures far exceeding 100° F., there succeeds a clear night during which rapid radiation and cooling takes place. Thus the rocks may undergo variations in temperature amounting oftentimes to a range of more than 75° F. within twenty-four hours. Such rapid and considerable expansion and contraction as this change in temperature involves cause the exposed rocks to crack or "scale." In this way large fragments of slight thickness may be broken off. Livingstone reports that in parts of Africa angular masses of rocks weighing 200 pounds and more are thus split from the parent ledge. Many instances of this method of rock breaking are reported from the high mountains of western America, and throughout the northern tier of states where the conditions are favorable.

Another mode of rock disintegration results from the different amounts of expansion exhibited by the various mineralogical constituents of a rock. When a piece of granite, for example, is raised to a moderate temperature, say summer heat or 78° F., the feldspar, hornblende, mica and other minerals composing it expand. The amount of expansion differs so greatly in different minerals that an uneven distribution of strains is produced throughout the mass which tends to loosen the interlocking grains. The continued annual and daily expansion and contraction of the rocks may cause them in time to break down into sand and gravel.

An effective agent of denudation at certain points in Maryland is found in the atmosphere in motion or the wind. As the wind blows over the surface of the ground or across bare exposed mountain peaks it catches up the lighter particles of soil and rock debris and whirling them up into the air, may project them with considerable force against opposing cliffs or other immovable objects. The effect upon both the rock particles and the objects hit is similar to that of a sand blast. Various cliffs in California, Arizona and other portions of the West have been carved into fantastic shapes by this natural sand blast. In South America the upper portions of certain cliffs have been so undercut that the remnants appear as huge boulders perched upon the ledges by some mighty transporting agent. On sandy shores, such as Cape Cod, or, in the wastes of the Sahara, the flying sands have been found to polish and plane down pebbles too large to be moved by the wind. Sometimes, as in the deserts of South Africa, the pebbles show longitudinal scratches and grooves worn in them by the flying sands.

Besides thus aiding in wearing down the resistant rocks, the wind also modifies the earth's surface by transporting sand and soil from one point to another. In this respect the destructional and the constructional effects of the wind merge into each other. The destructional process was illustrated in an interesting manner last year when the Loch Raven reservoir was being cleaned out. The cleaning necessitated the drawing off of a considerable portion of the water, as the result of which a broad shoal of mud and sand which had collected

near the upper end of the Loch Raven gorge was laid bare. This flat being exposed to the hot September sun and brisk winds became thoroughly dried, until the grains of sand no longer cohered. The prevailing west wind "drawing" into the narrow chasm caught up the dry sand, and, driving it out of the channel, drifted it upon the road at the curve, covering it to a depth of nearly a foot. In a somewhat similar manner great quantities of sand are annually carried from the long sandy beaches of our Atlantic coast line and either driven out to the sea or into the lagoons between the beaches and the mainland. In arid regions the wind may become a very important agent in the removal of rock debris.

Thus the atmosphere is seen to furnish chemical agents for rock solution and decay, to aid in the mechanical disintegration of the rocks through its changes in temperature and to carve or transport the finely ground products of their disintegration.

Aqueous Processes.

Pure water falling upon the bare rocks of mountains or wind-swept ledges on the lowlands would have but slight effect chemically in breaking down the rocks into rock debris and into the finer particles which make up the soils of the earth's surface.

Atmospheric water commonly contains in solution in small quantities nitric acid, ammonia, and carbonic acid as well as other less important substances, so that the rain upon reaching the earth is a powerful chemical agent, which can produce important changes in the rocks of the earth's crust. Rocks containing iron-bearing minerals, such as iron-pyrites, the amphiboles, pyroxenes, etc., also suffer considerable disintegration as a result of oxidation or rusting out of those minerals. The oxidation also involves at times an increased size or swelling of the altered mineral, so that physical strains and dissociations may also be effected.

Of great importance is the process of hydration or the chemical combination of water in certain minerals. This change generally accompanies the oxidation of the rocks and causes even greater increase in volume than does the latter process. Some of the hills of Brazil are believed to have been increased in height by this means,

which may be readily understood when it is learned that the transforming of granitic rocks into soil by hydration entails an increase in volume of 88 per cent.[1] The rocks of the Piedmont Plateau region of the eastern United States have been deeply affected by this alteration in their physical condition. For many feet below the surface there extends a zone of rock which has suffered hydration and consequent swelling of the altered minerals. When a block of this hydrated rock is brought to the surface it keeps its shape and compactness only a short time; soon it crumbles away like a piece of air-slaked lime.

Besides the chemical agents which the rain washes and absorbs from the atmosphere there are powerful organic acids which the decaying vegetable and animal remains lying on and in the soil furnish to the waters percolating through it. These substances added to the water make the moisture which pervades all rocks and soils a very powerful and active agent in their disintegration. Clearly a district whose rock foundations are thus weakened by chemical and physical changes will offer but slight resistance to the attacks of rain, rivers and waves.

The rich soil and the even-floored valleys which characterize limestone and marble areas have resulted from the rapid and uniform removal of the carbonate of lime in solution in the soil-water and by the streams. It has been estimated that 275 tons of lime or calcium carbonate are annually dissolved from every square mile of the Calciferous limestone of the Appalachian region, and this limestone is but one of several different beds which occur in that region. But these solvent waters attack not alone the yielding limestones. Granite, gneiss, sandstones, shales, quartzites, all yield more or less readily to its attacks, and none escape without some loss.

Striking illustrations of the great solvent power of the waters of the earth's surface are furnished by the corroded surfaces of quartzites, metamorphosed siliceous conglomerates and other siliceous rocks. One need but to go on an excursion to the rocks of Deer creek in Harford county, and, climbing to the summit of the ridge, stand on the projecting ledge which overlooks the gorge from the south in order

[1] Merrill, op. cit. p. 188.

to have under his very feet a striking illustration of the inability of the resistant silica or quartz to withstand the great solvent. The rocks at this point are a fine-grained siliceous sandstone and a quartz conglomerate which have been much metamorphosed or mineralogically altered under great pressure, and have, in consequence, been thoroughly impregnated with a secondary deposit of silica. Such rocks form one of the most resistant combinations which the earth presents to the elements, yet the surface of this ledge is pitted with shallow basins from three inches to one and a half feet in diameter and one to three inches in depth, which have been gradually dissolved out by the standing rain water. Little runways or channels generally connect one basin with another or lead out to the edge of the cliff. No lichens of corresponding sizes grow on these rocks, and the slight undercutting of the walls of the basins at a line corresponding to the average level of the water indicate that they are the product of aqueous solution. Similar basins and channels may also be seen developed on the exposed crests and ledges of quartzitic sandstones which form Dan's mountain, Backbone mountain and a number of other localities in this state and elsewhere. With examples of such intensity of action it is less surprising to learn that T. Mellard Reade[1] finds data according to which he estimates that England and Wales annually lose through solution an average of 143.5 tons of material per square mile, and this does not apply only in limestone areas but is an average for all the different rocks.

Powerful and important as are the chemical ways in which water aids in denuding the land, the mechanical action of this agent is of equal importance and generally much more striking. One of the important processes of denudation is the splitting of rocks by frost action. All rocks are more or less porous and contain water, while most rock masses are traversed by numerous sets of cracks called joints, and by finer partings, rifts, seams or the like, all of which permit water to penetrate below the surface of the ledges. The elevated and exposed peaks of all zones and the ordinary ledges of the Temperate and Arctic zones are all subject to frosts and thaws intermittently during the winter months. These sharp, sudden frosts

[1] Merrill, op. cit. p. 194.

seize on the water imprisoned in the pores, joints and cracks of the rocks and by the expansion, which results in the formation of ice, cause a tremendous pressure to be exerted against the sides of the confining crevices. The great power exerted by this expansion of freezing water may be judged from the calculation that the walls of a crevice which thus confines frozen water are subject to a pressure per square foot equal to the weight of a column of ice one mile high or about 150 tons. Successive frosts and thaws are thus able to split off innumerable small chips and to gradually work out huge blocks which later are by the same process reduced to sand. Pike's Peak in Colorado, a granitic mass, has large talus slopes wholly composed of angular fragments which have been thus split from its crest and sides. All the mountains and ridges of western or Appalachian Maryland show the results of the same action. Along the roadway to High Rock and Mt. Quirauk in the Blue Ridge may be seen fine examples of talus slopes composed of huge frost-riven fragments of the enduring quartzite which makes the ridge. Steep slopes of such fragments line either side of "The Narrows," as the gorge of Will's creek at Cumberland is called, and there furnish, already quarried, inexhaustible materials for constructive purposes and for railroad ballast.

Frost action does not stop with the breaking down of lofty mountains or scarred precipices, but continues to work over the coarse material thus furnished, converting it finally, with the help of the agents already noticed, into the rich soils which support the crops of the country; thus, although frequently damaging to a few crops, it is of the greatest help to the farmer, since it readily reduces almost to powder the stones of his fields and continually enriches the soil by bringing to it new material from the original sources. A striking illustration of the splitting action of freezing waters is found ready at hand in the unsightly scaling which disfigures houses and trimmings of sandstone. The sandstone commonly used in Maryland is very porous and readily absorbs water during a rain or snowstorm. If a frost comes while the stone is thus soaked the freezing of the imprisoned water causes it to split or scale off, particularly in

a direction parallel with the original bedding. Grace Episcopal Church, Baltimore, gives the best illustration possible of this process and its results.

Most of the processes which have been discussed so far have resulted in the disintegration or solution of the rocks of the earth's crust, thus preparing them for transportation. We have also to consider water as an agent of denudation and transportation combined. There are two forms of water which act in this double capacity, namely, ice in the shape of glaciers and floating ice and liquid water in the rills, brooks, rivers, lakes and oceans.

A portion of the water which falls as rain sinks into the soil and rocks as has been shown; a very fair proportion is evaporated and goes back into the air again; and a comparatively small proportion runs off on the surface. The latter portion is familiar to most of us, as the formation and growth of rills during a shower is easily observed. No rill, however small, runs down even a sodded slope without catching up at some point a fragment or two of soil. Soon the rills unite to form a small run which rushes downward still faster, carrying the fragments which loaded the rills and acquiring more soil and pebbles by its own strength. In this way the stream carves for itself a gully or channel. The waters gather into brooks and creeks and rivers, each increase in size and volume being accompanied by an increase in the amount of soil and rock debris which the streams bear onward. As has been shown, the streams thus transport and carry away from the surface of the land not only what has been broken off mechanically by frost, wind, temperature-changes, etc., but also what the waters succeed in dissolving away by chemical means. The streams not only carry away the soils and dislodged fragments of rock, but also do some breaking themselves. The small rill or rivulet carries fine grains of sand which it knocks and pushes against the soil and rocks over which it flows; the brook, with the larger volume, rolls pebbles along its course; and the mountain torrent transports large boulders. These rock-fragments the streams use as tools which they continually hurl against the bottom and sides of their channels, thus wearing away the rocks and cutting their

valleys deeper and deeper. In the course of down-cutting untold numbers of boulders are reduced to powder, but eventually the channel is cut almost to the level of the sea.

Thus the rains are working to wear away the general surface of the land by washing down the soils and to deepen the streams by giving means of transportation and movement to their tools.

The snow collects on lofty mountain tops, and gradually sliding down under the force of gravity, begins to solidify into the ice of glaciers. The glaciers moving slowly, perhaps not more than one inch in a day, push on irresistibly until they melt away. Rocks roll down the slopes of mountains, and lodging on the glacier gradually melt their way down to the bottom of the ice-river, and there, with other fragments which the moving ice has plucked from its bed, serve as cutting tools whereby the glacier deepens and widens its channel. When glaciers combine and grow to such a size that they cover the half of a continent, as was recently the case in North America and Europe, they scrape off the loose rock and soil and grind and polish the rocky ledges below until they gradually wear away the surface.

On the seashore the waves of the ocean are continually beating against the land. The great breakers of storms hurl many tons of water against the projecting rocks of the coast, and the water penetrating every crack and crevice subjects these rocks to enormous hydrostatic pressure. In this way great and small blocks are gradually split from the cliffs and reefs and fall to the foot of the beach. Here the waves seize the fragments which they have broken off above, and hurl them against the rocks below. Thus the ramparts of the land are gradually battered down and undermined, and broad submarine shelves appear. On sandy coasts the weak cliffs give way rapidly before the waves and are driven back until the sands which they have furnished form a broad shallow shelf on which the waves must break until they have removed it and can again reach the cliffs.

Organic Processes.

Organisms aid the general reduction of the land in various ways which, although often of small moment individually, are very pow-

erful taken as a whole. The fine frost- or heat-riven fragments of the rock suffice to support at first a few simple plants and lichens. These send out their roots in search of food and penetrate the fine crevices of the rocks. The roots, continuing to grow, split the rock-pieces apart as they increase in size and thus furnish more material for the soil in which they grow. When the trees strike root in the soil collected in rock-crevices their roots often exert power enough during their growth to split off large boulders. Every plant clinging to the face of a cliff, every clump of moss or lichen fastened to a rock, is aiding in the breaking down of the rock by its growing roots and by the various acids which it produces. Even the minute organisms known as bacteria, by reason of the nitric acid which they liberate in the course of their growth and their presence in countless myriads throughout the cracks of the rocks, exert a not inconsiderable disintegrating influence upon the rocks in which they lodge. Merrill says (p. 203), "The organisms act even upon the most minute fragments, reducing them continually to smaller and smaller sizes."

To the accumulated soil are added, in the course of time, the remains of plants and animals, which yield in the process of decay various acids, that are taken up by percolating waters and further distributed through the rocks, where they aid in their chemical and mechanical disintegration. The evacuations of various animals, such as ants, also afford supplies of disintegrating acids.

Burrowing animals, such as rabbits, squirrels, prairie-dogs, earthworms and the like give important aid to the denuding and transporting agents by keeping the soil loosened and pervious to rain and moisture. Darwin found that earthworms, by continually transporting earth to the surface from their burrows beneath the large stones in the pastures, have been largely instrumental in the gradual burial of these rocks, thus materially aiding in the disintegration of such masses. Considerable quantities of decaying organic matter, such as litters of dead leaves, scraps of food, excrement and so on are also generally to be found in animal burrows and thus another very fruitful source of organic acids is afforded.

Summary.

From the foregoing it appears that a multitude of agents and processes are incessantly at work all about us, tending to break down the rocks and to wash the debris thus produced into the valleys and thence to the sea. The gases of the air, the wind, the temperature changes accompanying the days and seasons, combined with the chemical and mechanical actions of the waters on the earth's surface and the organisms which live thereon, are all striving to reduce the lands that stand above the sea. Clearly, if these forces, unmodified and undiminished, continued to act indefinitely, the continents and islands would not long remain above sea-level. Since the subaërial agencies would work much more rapidly than the waves they would first be reduced to smooth, featureless tracts, whose inclination seaward would be just sufficient to carry off the water which falls as rain. Then they would gradually yield to the attacks of the waves, and in the end would be planed off to more or less even surfaces some feet below low tide, forming wave-cut submarine benches and platforms. Geikie[1] estimates that the continent of Europe would be reduced to sea-level in about four million years if exposed for that length of time to the attack of atmosphere, rain, and rivers, and supposing these to work at the same rate that they do to-day. In the same period of time the sea-waves would cut away a strip of land along the shore less than one hundred miles wide, considering them to advance at the rapid rate of ten feet per century. Another authority[2] estimates that the waves remove annually one cubic kilometer of material from the land, while the subaërial agencies are carrying away not less than fifteen times as much.

When all the above considerations are kept in view, together with the fact that the surface of the land is well supplied not only with high hills and minor elevations, but also with many lofty mountain chains and plateaus, it is patent that there must be constructional processes at work counteracting the destructional ones which have been described. They will be discussed in the following pages.

[1] Geikie, A. "Textbook," 3rd ed. p. 467.

[2] de Lapparent, quoted in Scott, W. B. "An introduction to Geology." pp. 303-4.

PROCESSES OF CONSTRUCTION.

Crustal Movements.

The most important of the processes which are at work counteracting the destructive effects of denudation are those movements of the earth's crust which are tending to elevate it above the level of the sea.

These movements are of two general kinds or classes. One class includes those movements of the earth's crust which extend over areas of continental extent and do not result in the appreciable dislocation of the strata through folding or tilting. These movements are sometimes called *epeirogenic.*

The second class of movements and dislocations affect restricted portions of the continental plateau and are expressed as foldings, tiltings and faultings of the different crustal elements. They are the fundamental movements whereby mountains attain their elevation above sea-level. Such movements are therefore called *orogenic* or mountain-making. Many familiar examples of such movements and dislocations might be cited. The best known to Marylanders are the long ridges and mountains of the Appalachian province of the state formed by the folding and faulting of the Paleozoic strata of that district. The Blue Ridge also is the result of the pushing of a big block of hard sandstone and volcanic rocks over the easily eroded limestone of the Cumberland or Hagerstown valley. In the west the Sierra Nevada and the Great Basin ranges are formed of huge blocks which have been broken or faulted and then tipped up so that one edge of the block forms the crest of the mountain range. All such mountains have had their present physiognomies carved out during and since their elevation by the various denuding agencies above described.

Volcanic Eruptions.

The ejection of lava, volcanic ashes, scoriae and the like from volcanic vents are very effective and important agents of construction in some localities, but they have not recently affected the surface configuration of Maryland. The sheets of diabase which characterize the sandstones of the Newark formation, and the acid and basic volcanics of the Blue Ridge district show, however, that volcanic activities were present in Maryland in past geological ages.

Subaërial Processes of Construction.

In discussing the denudation of the land, several references were made that indicate the *constructional* activities of agents and processes mainly and ultimately destructive.

Thus the wind-whirled sand which carves out the standing rocks of the shores is spread over the surface or formed into dunes so common and characteristic of the whole Atlantic coast of America. The sand blown from the beaches is also often dropped in great quantities into the lagoons behind them and thus becomes an important factor in bringing about their conversion into dry land.

Aqueous agents are also active builders. Deposits from evaporating waters about mineral hot springs often build important topographic features such as the great terraces and basins of the Yellowstone National Park. The mechanical deposits from running or standing waters are the most numerous and important of the constructional forms built by water. Among these are the talus-cones and flood-plains and deltas of rivers, and the beaches, spits and bars produced by wave action in lakes and seas. The great ice-sheet of the Glacial Period, and the smaller glaciers of lofty mountain areas have left very striking constructional topography in the form of terminal moraines, eskers, drumlins and kames. From these examples it may be seen that water in its various forms has constructive as well as destructive effects.

Organic Processes.

Small plants living in the waters of various thermal springs are now known to be very effective in promoting chemical deposits. On the slopes of dunes and on other sandy areas are coarse grasses and shrubs and sometimes even trees that, on account of the binding power of their roots, protect the sands from further removal. Similarly, the grasses and sedges of the mud-flats and marshes, by retarding the currents flowing over them, cause the deposition of silt, while their long roots, matting together, convert the mud thus deposited into a more or less resistant mass.

Summary.

Constructional processes thus fall into two great divisions: first, those which originate in movements of the earth's crust resulting in uplift, and second, those which accompany the progressive denudation of the land. The essential process which must precede all degradation is uplift, and this may either be continental (epeirogenic) or mountain-forming (orogenic). These movements, gradually progressing, permit the agents of denudation to become effective, and thus minor constructional features, such as dunes, flood-plains, deltas and the like are produced by agents which are on the whole destructional in their results. These minor features, however, are not as permanent as the hills and mountains which are carved out of the uplifted areas.

It is apparent, then, that there are upward movements which counterbalance the wearing away of the land's surface, and that these uplifts are at present somewhat in excess of the downward tendency. This is more clearly seen by the study of geographical boundaries as they existed in former geological periods. In the course of ages America has grown to its present size from being comparatively small in area and confined to islands over what is now Canada, northern central New York and the Piedmont Plateau of the Atlantic Slope. The very last emergence added a strip of land one hundred to two hundred miles wide to the eastern coast of North America from Long Island south to Mexico and Yucatan.

Although the study of ancient geographical boundaries or paleogeography is very interesting, and there is much material within the state of Maryland for such investigations, this will be left for a future paper. At present the development of certain typical river systems and the topography which they have carved out are to be considered.

DRAINAGE DEVELOPMENT.

A Topographic Cycle.

It seems possible in the light of the more recent investigations in physiography to deduce certain general laws concerning the develop-

ment of the relief of the earth's features. Those districts which can be shown by geological evidence to have been long above sea-level are generally found to have mild forms of relief, while the recent elevations commonly have strongly marked topographic characters. Such regions, for example, as the Piedmont Plateau of the Atlantic Slope of North America, the Scandinavian peninsula, portions of central Germany and northern France, have stood at relatively the same elevation above sea-level for long periods and are found to have a mild and rounded topography, while the Alps, the Himalayas, the Coast Ranges and the Grand Canyon of the Colorado have been carved out during geologically recent times and are regions of strong relief.

Among the various cases just cited different grades or degrees of topographic relief may be shown to exist. Thus, for example, the geological date of uplift of the Himalayas is known to be earlier than that of the Coast Range, and an examination of the drainage reveals the fact that the streams of the former district are somewhat more intricate on account of the longer time which they have had to extend their branches. Again, in the recent Red River basin of the North, the streams are still less minutely branched than are those of the Coast Range.

If now the drainage of a newly emerged or recently elevated district be followed through the several periods of its development, it is possible to find all these various types of drainage occurring in a natural and appropriate sequence. As the rains fall upon the slightly uneven surface of the old sea-floor the waters gather in the inequalities of the surface, forming lakes or, combining as streams, run down the steepest slopes they can find to the sea. The directions taken by these newly-formed streams are wholly consequent upon the original inequalities of the surface and its slope. It will appear later that such streams whose courses are determined by, or coincident with, courses which would result from, original configurations of the surface are common enough to be classed together as a type. They are, for convenience, called *consequent streams.*

At first these consequent streams are small in volume, but repeated rains gradually increase the size of the streams and they begin to

carry away the debris which the elements and their own powers loosen from the surface. Thus efficient tools are provided, and the streams begin to sink their channels rapidly, since along those lines are concentrated the greatest activities of the running waters. The first result is the excavation of a deep canyon or gorge, this work beginning at the mouths of the streams and progressing rapidly headwards. While the narrow canyon is being pushed towards the head of the stream, along the lower course the gorge is beginning to widen as the result of the action of frost and rains. Widening is greatest at the top of the canyon, which is the portion first and longest exposed to the weather, and, except at the extreme upper end, where the gorge is youngest, its cross-section will reveal a flaring top.

The stream will continue to cut down its channel until it has produced a slope whose inclination seaward is the minimum required to carry down the water. When such a slope is reached, then the stream begins to lose its downward cutting powers and works more and more against the sides of the canyon, and we thus have a second reason for finding the canyon wider at the mouth of the stream. The deepening of the main channel goes on faster than does that of the side streams, but as the accomplished grade progresses up stream the tributaries, heretofore unable to keep up with the rapid down-cutting, now begin to adjust their slopes also. Until the lower portions of main and side streams are thus adjusted, however, the as yet unaffected headwaters do not feel the effect of the uplift and can accomplish but little in the way of erosion. There is not, then, at this stage in development, a large number of side streams, and the divides are broad, flat, poorly drained, and sometimes even marshy. The whole district has an appearance somewhat like that shown in Fig. 1.

As this general stage in the drainage development is the one passed through immediately succeeding the birth of the new land it may be appropriately termed *Infancy*. It is by no means an imaginary topographic phase. Many illustrations of such topography could be brought forward. The drainage and topography of the Coastal Plain, particularly that portion lying in Maryland, still car-

ries the ear-marks of this period in its development. The wandering courses of the Chester, the Choptank, the Patuxent, the lower Potomac, etc.; the deep gorges now half filled by the waters of the sea and the bay, which have been cut by the streams of southern Maryland; and the level remnants of the original Lafayette surface, which are still to be found at points remote from the attacks of the largest

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FIG. 1.—View of model illustrating topographic youth.

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FIG. 2.—View of model illustrating revived topography.

streams, all indicate that the Coastal Plain is not long past its infancy. The classic example of infantile drainage and topography is that great gorge already referred to, the Grand Canyon of the Colorado, but it is not wholly typical on account of the desert conditions.

The rapidly increasing number of small streams along the sides of the canyons, the continued beating of the rains and the winds, in fact, all the active processes of denudation, since they never cease in their activity, do not permit the newly started streams to retain

such infantile characters long. The steep walls are gradually worn back, and the few original consequent tributary streams, having cut down their lower channels to the grade of the main stream, begin to push back their headwaters. New side streams spring up along the walls and slopes of the gorge, cutting deep scars and seams in them, and thus hasten their recession. As the number of tributaries increases the broad flat divides are narrowed and even begin to lose their flatness. The lakes which formed at first have their outlets cut down and are drained, while the channels of the older streams, which were rough and broken by falls and rapids, gradually lose their inequalities. The volume of the main stream is somewhat increased by the growing number of side branches, but as each one of these comes down laden with the debris which its active little headwaters and its steep banks furnish, a great load is soon added to it. All of this load the larger stream cannot manage to transport, and so some portion is dropped at the mouths of the several tributaries, forming cone-like alluvial deposits that project into the main valley, while part is taken by the master stream and is used by it to steepen its slope, thus enabling it to carry off a greater load. Many streams in this stage may be found among the high lands of the Sierras, the Himalayas and other regions of plentiful rainfall and recent elevation. Excellent examples may be found in certain portions of Southern Maryland. In St. Mary's county numbers of the southwestward flowing streams show these adolescent features, with the over-loading of the main stream and consequent flood-plain building.

The constant increase of the catchment area by reason of the ever growing number of streams and the pushing back of the headwaters, continues until the divides between opposing streams, whether of the same or of different drainage systems, are sharp and steep. The ramifying branches have sought out every square mile of territory, so that the whole region is completely drained. The small headstreams thus having no new territory to conquer by linear development begin to reduce the steepness of their own slopes, to soften their valley sides, and to reduce and round off a little the tops of the hills. Thus

the amount of mechanical sediment brought to the larger streams decreases while the volume of water still remains about the same. The main channels smoothed out still more are so far reduced that they describe smooth regular curves from source to mouth. Up to this time the slope of the river channels has been slowly changing, but it now reaches a period of comparative stability, since the changes in load and in volume, which are the factors determining the curve, are very much slower hereafter. The channel slopes are now more permanently suited to the needs of the streams and the latter may be said to have established graded channels. The accompanying figure shows the slope to be steepest at the source, but to rapidly decrease to a midway point whence it is of constantly but very gently decreasing fall to the mouth. As all the streams gradually approach such a graded condition, the inter-stream areas forming the divides also gradually wear down. Such an area is included within the

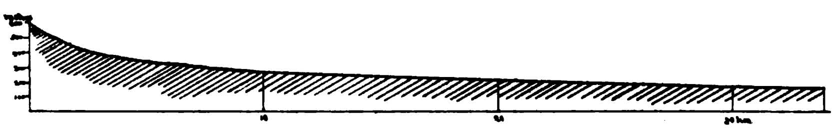


FIG. 3.—A normal stream profile (after Penck).

boundaries of the Piedmont Plateau on Plate III. Similar topography characterizes most of Northern Virginia and large portions of Eastern New England. The country and its drainage may be said to have reached its *Maturity.*

The gradual change in topography and in drainage which have just been briefly sketched presupposes, first of all, that the land and sea have remained constant to each other long enough to permit such development to occur. This supposition is not always justifiable, since multitudes of cases can be cited to show that after a period of rest long enough to permit of the topography developing to some stage earlier even than Maturity, earth movements have closed what may be called the current cycle and have inaugurated a new one. In order to make the series of topographic forms complete, however, some students have carried the scheme beyond the stage of Maturity and described yet another and final stage which has been likened to *Old Age.*

Suppose that after Maturity is reached, the same conditions endure for an indefinite period. The streams would still continue to deepen their channels although at an ever decreasing rate. The hills and mountains would gradually sink lower and yet lower, yielding now more to the solvent action of the waters charged as they would be with acids from the mantle of soil and vegetation which covers everything. Finally all slopes would be reduced to the lowest possible angles and the divides also would be very insignificant, except at points far from the mouths of the streams. The lowest zone would be along the sea-coast, where the land would be reduced quite to sea-level. From here inland there would be the slightest possible rise in order to permit the rains to really drain away and not gather into stagnant pools. The whole district would be nearly featureless and so closely approach a plain in appearance and contour that it might appropriately be called *an almost-plain* or *peneplain,* just as an almost-island is a peninsula.

It is obvious that the lowest level to which a land can be worn down by stream action is sea-level, and even this can never be reached except at the very shores, since some slope is needed to carry off the water. Therefore the ocean is called *the great base-level,* or the base down to whose level all the forces of Erosion or Denudation are working to reduce the land. *Local base-levels* may exist for a time, such as the level of a lake, which is the base-level for streams entering it, or the level of a stream where it crosses an unusually resistant stratum, which may be the base-level for its tributaries above this point. But eventually all the streams are controlled by the level of the sea. Such an enormous duration of time, throughout which the position of the land would have to remain fixed with reference to the sea-level, would be required, however, to permit of the production of such a complete peneplain, that there is scarcely any warrant for supposing that such a condition has often existed. Nowhere to-day can an example of such a topographic feature be found.

On the contrary, everywhere there is evidence to show that the land and sea do not long continue constant to each other. Young as

are the Coast Ranges of California, they had, since their elevation, attained very nearly to ripe Maturity, when great subsidences took place, drowning part of them. These accidents again were recently followed by successive lesser re-elevations. The eastern coast of North America has suffered repeated elevations and subsidences since the period of the last great elevations of the Sierra Nevada, and is still undergoing slight oscillatory movements. Other instances might be cited to show that the chances are probably small for a locality to reach even to the perfection of well-matured topography.[1]

Although the topographic cycle has perhaps never had an opportunity to run its full course, yet it is convenient for the purposes of understanding and explaining topographic forms to retain the conception of a complete cycle, which might be renewed, if, after attaining to the stage of a peneplain, the land were again elevated and the streams commenced their tasks anew. As we have seen, however, the rule is that at some stage in the ideal cycle the march of development will be interrupted. Such interruption may result from one or several causes. The most common interruptions come from re-elevation of the land, whereby the streams receive increased energy, or from depression, which allows the sea to invade a portion of what was dry land and reduce the energy of the streams by decreasing the height from which they have to fall to reach sea-level. When by reason of the rise of the land the streams renew the vigor of their own cutting, and begin to cut canyons below the general surface which they have before produced, they are said to be *revived.* The same phenomenon would be produced if, after long delay, the master stream of some system should succeed in cutting through a stubborn ledge and begin to work rapidly down through a more yielding understratum. It will appear farther on that most of Maryland's streams show the reviving effects of re-elevation. The illustration forming Fig. 2 shows a district of *revived drainage.* Depression whereby the lower courses of most of the rivers are submerged beneath the sea hastens the reduction of what is left above sea-level, and by decreasing the slope of the lower courses often

[1] See R. S. Tarr, "The Peneplain." Amer. Geol., vol. xxi, 1898. pp. 351, et seq.

causes the building of flood-plains at these points. The coasts of Maine, of Norway, and of Maryland afford excellent examples of such topography, which is called *drowned.*

Migration of Divides.

The progressive development of a piece of country through the stages of a Topographic Cycle is accompanied by many interesting processes, some of which will be considered in this and the following section.

When the broad flat divide which characterizes the infancy of stream growth is converted to the sharp serrated crests and ridges of earliest maturity, the streams, which before were battling against a common enemy, viz. the unreduced land mass lying between them, are then brought into closer rivalry. Each stream heading against a divide is endeavoring to wear it away and to gain more drainage area. If the streams are pretty evenly matched, then the divide must gradually sink down, until it becomes a low ridge almost exactly beneath the line along which the headwaters of the opposing streams first met on the surface of the plateau. Should it happen, however, that the streams on one side of the crest had an advantage over the opposing set then the rocks would be worn away unevenly on the two slopes; the stronger streams would wear away their side faster and the divide would move towards the weaker set of streams.

There are many ways in which one set of streams may come to have more power than an opposing set. The favored streams may have a shorter course to the sea, thus giving them a steeper slope, or what may amount to the same thing, the course may lie on softer rocks which, being more nearly reduced to the sea-level or base-level along the lower course, concentrate the greatest possible amount of steep slope at the headwaters. This is excellently illustrated in Maryland by the contrast in slope which exists between the tributaries of the Monocacy, a stream situated on easily eroded slates, sandstones and limestones, and the main streams of the Patapsco, the Patuxent and other rivers which have to cross the resistant gneisses and other crystalline rocks of central Maryland. Again, greater rainfall will give to one side larger volume and greater cutting powers. Excel-

lent illustrations of the advantage gained in the latter way are furnished by the streams on the western slopes of the Cascade, and the Sierra Nevada, and on eastern slopes of the Andes in equatorial America. Also a tilting of the land in the direction of the favored stream, by increasing the slope of the one and decreasing that of the other, may give advantage sufficient to cause a shifting of the divide. This particular method has been appealed to farther on in explaining certain anomalies in the drainage of the Maryland Coastal Plain.

Another way by which divides are caused to shift or change their positions arises from the attitude of the rocks. In districts underlain

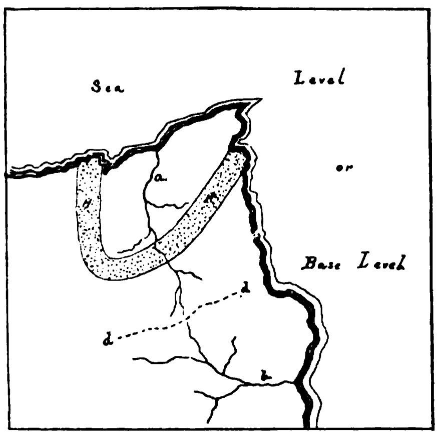


FIG. 4.—Diagram illustrating a simple shifting of divides.

by layers of alternating hard and soft rocks, which are inclined at an angle to the horizontal, the divides first tend to become located upon the hard rocks. For example if, as may easily be the case at birth, certain streams, such as *a* in Fig. 4, are so located that they cross the hard layers, then, because of the hindrance which they thus meet with, they can reduce their channels but slowly. This gives an advantage to streams located like *b*, which, being on yielding rocks, can cut down more rapidly. Therefore *a* must slowly retreat and *b* advance step by step until the divide *d-d* is located upon the hard band *H-H*. Once thus located, the divide will not tend to move one

side or the other, unless the hard layer be inclined, as represented in Fig. 5. In such an event it is evident that, as the land is denuded, the divide will follow down the dip of the strata, assuming the positions *D*, *D′*, *D″* successively. The tendency in all cases is to maintain divides upon the most resistant strata. Many instances of such a cataclinal or down-the-dip shifting of divides are furnished by the

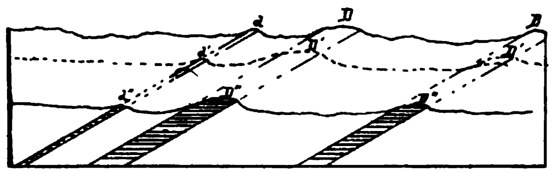


FIG. 5.—Diagram illustrating shifting of divide in a region of tilted rocks.

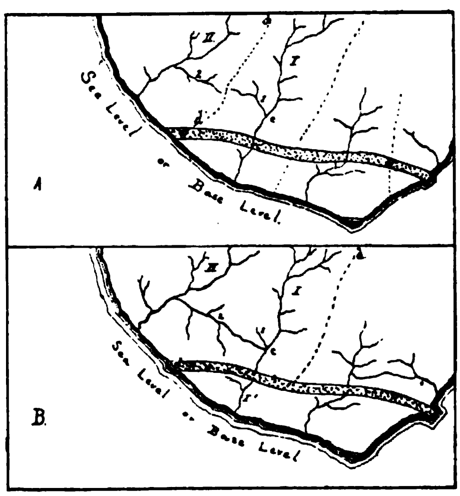


FIG. 6.—Diagram illustrating shifting of divides through stream capture.

Appalachian Province of Maryland. Shriver's Ridge, Big Savage mountain, Winding Ridge, Catoctin mountain and many smaller mountains are examples of such divides.

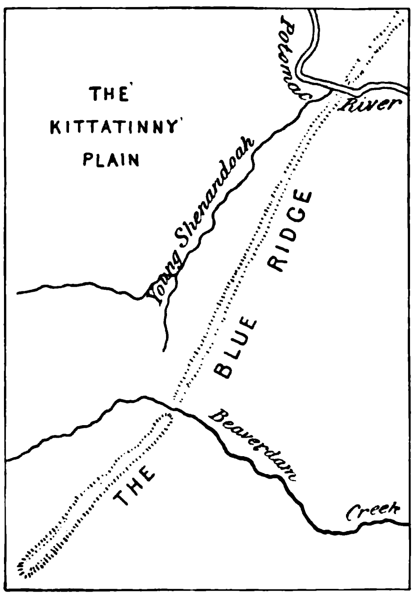
The manner in which divides or watersheds migrate has been brought about generally by a slow, gradual shifting. Divides between two river systems or two parts of the same system may at

times shift suddenly. Thus, as shown in Fig. 6, one stream *I*, perhaps the larger, has to cross a very refractory band *R* on its way to the sea, while the other stream *II* traverses yielding rocks along its whole course. In the course of time the second stream *II*, by reason of its easier path, will reduce its channel to a much lower level than it is possible for the first stream *I* to do along that portion of its course above *R*. Thus more power is gained for the side streams of *II*, and they are enabled to push back the divides until *I* has been intercepted at *c*. Owing to the low level of the channel of *II* and its tributary 2, *I* is turned into the valley of 2, leaving its lower course to flow on as a shriveled, *beheaded* stream. This change in river courses shifts the divide gradually at first, then with a bound from *d-d* to *R*, again illustrating the law that hard rocks tend to form divides, soft rocks to form valleys. When the arrangement of the streams is not in accord with this the conditions may be regarded as anomalous and disturbing, or modifying factors may be looked for.

Many illustrations of such cases of river piracy and capture can be found in the Appalachian region of eastern North America. A single example found in the neighborhood of Harper's Ferry may be cited here. Others will be considered when the Appalachian Province of Maryland is described. In Fig. 7 is represented a bit of drainage along what is now the Shenandoah Valley and the Blue Ridge. At the period represented the whole Atlantic slope probably appeared as a broad, gently rolling plain. This plain was but slightly interrupted by the low crest of the Blue Ridge which the Potomac river and Beaver Dam creek crossed through low shallow water-gaps. Beyond the eastern limits of the figure Beaver Dam creek joined the Potomac. The young Shenandoah had begun to develop along the broad band of limestones which lie just west of the hard quartzites and volcanic rocks forming the Blue Ridge.

Shortly after the time represented in Fig. 7 the whole eastern slope of North America was tilted and raised. This elevation revived the streams and they began first to deepen their channels and then to push back their headwaters and sidestreams. The Potomac, with

its large volume, rapidly sank its channel through both the limestone and the hard rocks of the Blue Ridge. Thus the mouth of the Shenandoah was lowered and this stream began to push back its drainage basin. Beaver Dam creek also felt the effects of the revival, and would have done battle with the growing Shenandoah for the mastery of the area west of the Blue Ridge; but the creek was seriously handicapped, for it could not work back faster than its small volume could cut down its gap in the Blue Ridge while the Shenandoah had the



From National Geographic Monographs, American Book Co.

FIG. 7. FIG. 8.

Examples of river piracy (after Willis).[1]

aid of the powerful Potomac. So it resulted that the Shenandoah worked faster than Beaver Dam creek was able to do, and finally capturing the headwaters of the latter stream led them off to the northeast, leaving the beheaded stream to continue with the Blue Ridge for its future western boundary. As the Shenandoah grew in vol-

[1] The Kittatinny Plain is referred to elsewhere in the text under the name of the Schooley Peneplain, a term earlier employed by Davis.

ume, by further captures of a like character, its valley deepened and widened up to the foot of the mountains; the gap in the Blue Ridge where Beaver Dam creek formerly crossed was left high and dry as a *wind-gap,* forming a deep notch in the crest of the Blue Ridge; and a small stream flowed westward from the edge of the gap down into the Shenandoah, taking a slope and direction exactly the reverse of the one formerly held by the creek. Thus was developed the later drainage shown in Fig. 8.

Relations of Streams to Structure.

In studying the location and migration of divides, it has been seen how much the streams are influenced by the relative positions of the yielding and the resistant rocks; how divides may change their positions and finally come to coincide with the bands of resistant rocks or with those rocks most favorably situated for resisting erosion. In the processes of divide-shifting, the streams which have the most favorable locations either as regards rocks or in relation to base level or both, have been found to be the most successful in extending and developing their courses. From these considerations it is to be expected that wherever the various strata are of varying degrees of resistance and are arranged in an orderly manner, as is the case in the Appalachian districts, there the streams are to be found expressing the arrangement of the strata as they come to the surface. The valleys would be located on the more yielding rocks, while the inter-stream areas and divides would be formed by the resistant strata.

The manner in which such arrangements are perfected is simple. As the newly exposed land rises higher and higher and the youthful streams born upon it cut deeper and deeper, they discover the various strata which form it. If the beds are horizontal and undisturbed, as is the case in the Coastal Plain, and approximately so in the Alleghany Plateau, then the surface of the land does not present long belts of various rocks but is largely covered by one stratum. In such a case a peculiarly irregular branching of streams which is uncontrolled by variations in rock character is developed. This class of streams, called *autogenous,* is specially described in the chapter on the Coastal Plain. It is also characteristic of West Virginia plateau districts.

When the new land emerges from the sea and is folded into long troughs and ridges, as was the case in the Appalachian district, the streams find very different conditions of development. They at first take courses consequent upon the folds of the strata and thus collect in the lowest troughs, passing from one trough to the next by the lowest sags in the dividing, arched ridges. As the streams cut deeper, the small consequent streams flowing down the sides of the long ridges, and the larger streams, where they flow through sags in the crests of the ridges, saw through the various strata and reveal the hard and soft, the resistant and the yielding layers. After these first cuts are made streams rapidly develop along the yielding bands, and, by the shifting of divides through capture, the rivers one by one come to be located on these strata. At various points the larger streams, able to cut down rapidly, maintain the consequent positions which they assumed at birth and cross from one belt of soft rocks to another in spite of the hard intervening ridge. The valleys on the soft rocks which are opened up after the birth of the streams are called *subsequent* valleys, and their streams subsequent streams, because their origin is subsequent to that of the consequent streams. As the streams progress towards Maturity, further adjustments serve to bring nearly all of the earlier subsequent streams and each of the younger ones into close accord with the arrangement and structure of the strata. The resulting stream-pattern will thus clearly show the direction of the underlying rocks. In the Appalachians, where the strata lie in long parallel folds, the streams have developed into a peculiar pattern like that made by the branches of a grapevine on a trellis, which is sometimes spoken of as a *trellis* or *grapevine system.* Its characteristics are shown in the arrangement of Bluestone river in Fig. 9. The same illustration also shows, in its upper left-hand corner, the irregularly arranged drainage which has developed on the horizontal beds of the Cumberland Plateau lying northwest of Alleghany Front and beyond the Bluestone river.

Where the rocks are faulted and tilted instead of being regularly arched and folded, the streams also arrange themselves along subsequent courses, but as the relations of the various beds are not as reg-

ular as in the case of simply folded strata, the stream pattern is not usually as regular in its development.

In areas of crystalline and metamorphosed rocks which have lost all traces of stratigraphic relations but still retain their relative powers

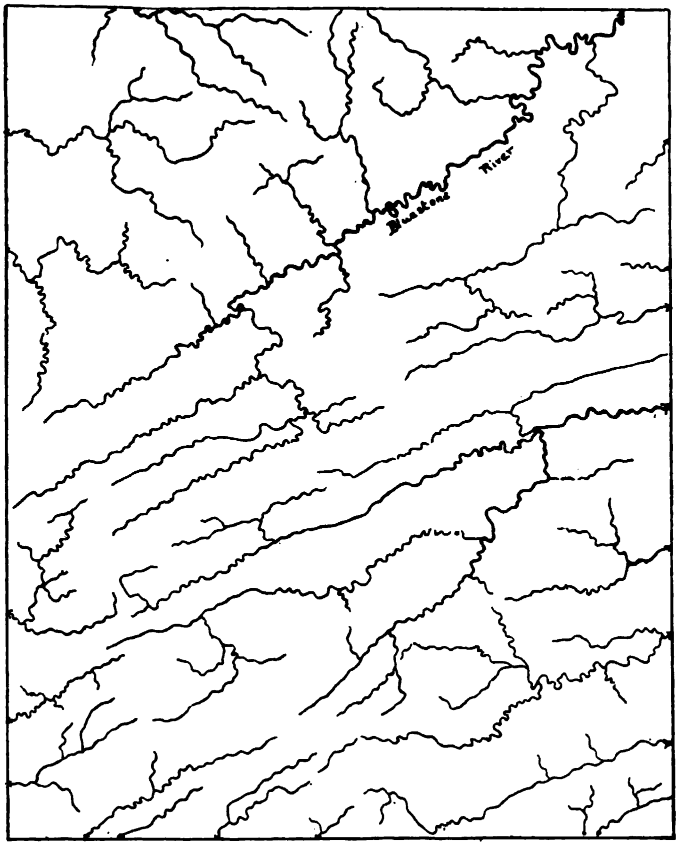


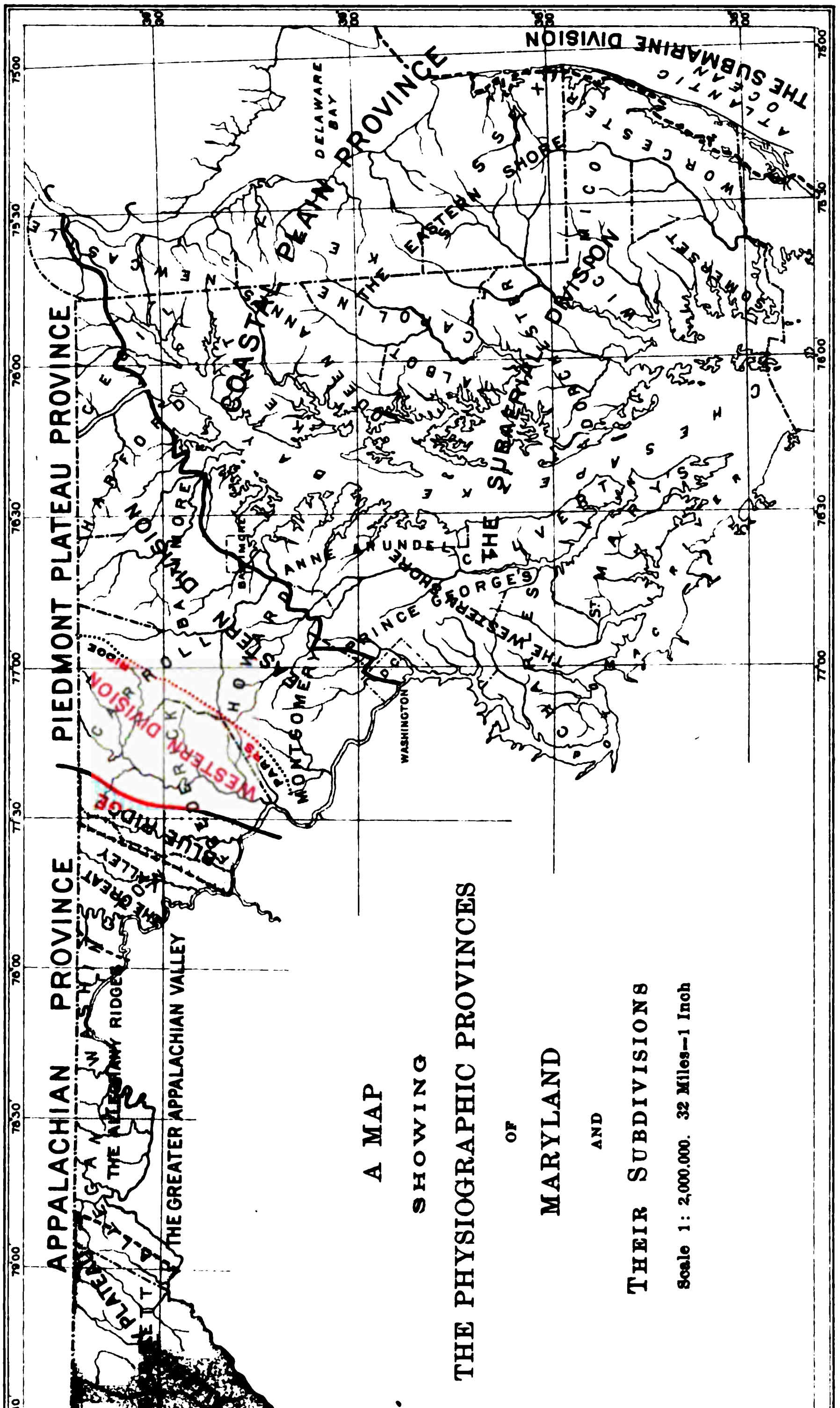
FIG. 9.—Streams adjusted to Appalachian structure (after Willis).

of resistance and some sort of banded arrangement, it is to be expected that the streams would still show certain adjustments to the rocks which they encounter. The particular features of such adjusted drainage will be treated of further on, but, in general, it may be said that the smaller streams and many of the larger ones would

normally be found arranged in accordance with the directions of least resistance.

Although streams are normally affected by the rocks with which they come in contact in accordance with their degrees of resistance, these laws are not always operative. For example, the Potomac river cuts across the hard ledges of the Appalachian district fully as often as it turns and flows parallel with the direction of these ridges, in the valleys located on yielding strata. The points where this river cuts through the high ridges of hard conglomerate or sandstone are rarely points where it would have located if it had developed its position normally as many of its small tributaries have done. Various other features of the Potomac are anomalous, and to explain them it is necessary to go back to a time when, as will be explained in another place, the river was a large stream meandering from its source across a broad peneplain to the Atlantic. It has already been remarked above that when a land is reduced to a peneplain its streams are bordered by broad flood-plains in which they wander almost at random. It is not to be wondered at then that the Potomac, when it reached this stage, wandered from the well-adjusted course it had secured to itself during its maturity. A subsequent uplift set all the streams to cutting down and again caused the river to trench itself in its random, unadjusted course, thus preserving its senile wanderings for us to study. One way in which lack of harmony between streams and structure may be brought about is thus seen to be the wandering of streams during Old Age or under peneplain conditions.

When an area is wholly buried beneath a blanket of younger rocks or sediments, the streams which arise upon the new series of deposits take their courses quite independently of the structure of the rocks buried beneath them. Continued erosion may carry these streams down through the overlying strata upon the lower series and the stream courses will then be at variance with the arrangement of the latter rocks until sufficient time has elapsed to permit of a readjustment of the courses to the newly discovered conditions. Such a state of affairs will result when the streams at present draining the Coastal Plain blanket of sediments described in the next chapter, shall have


A MAP
SHOWING
THE PHYSIOGRAPHIC PROVINCES
OF
MARYLAND
AND
THEIR SUBDIVISIONS
Scale 1: 2,000,000. 32 Miles—1 Inch
APPALACHIAN PROVINCE
PIEDMONT PLATEAU PROVINCE
COASTAL PLAIN PROVINCE
THE SUBMARINE DIVISION
THE EASTERN SHORE
THE SUBAERIAL DIVISION
THE WESTERN SHORE
EASTERN DIVISION
WESTERN DIVISION
BLUE RIDGE
THE GREAT VALLEY
THE ALLEGHANY RIDGES
THE GREATER APPALACHIAN VALLEY
DELAWARE BAY
ATLANTIC OCEAN
WASHINGTON
LITH. BY A. HOEN & CO. BALTO.

cut through these and reached the underlying Piedmont rocks. This will be more quickly understood by referring to Figs. 11 and 12.

Another type of superposition is seen when a stream cuts down through a yielding stratum and comes in contact with a hard bed which it would have avoided had not the overlying softer bed tempted it. Illustrations of this are not infrequent in the Appalachians. It appears that Braddock's Run, near Cumberland, was for a short time thus superposed across Wills Mountain.

There are other ways in which a region formerly characterized by well-adjusted drainage may have its streams thrown out of adjustment. The country may be buried beneath extensive flows of lava, such as characterize the Deccan plateau of southwestern India or the great lava plains of the Snake river in Idaho. A great ice sheet, with its attendant deposits of till, sands, gravels and boulder clay, may so alter the face of the country, as has been the case in northern North America and Europe, that scarcely a single mile of any stream's course can now be pointed to with certainty as having been established before the advent of the ice. To this disturbing agency New England owes all its picturesque lakes and ponds and the many waterfalls along the altered courses of its rivers, which by their great resources of power for driving mills have made the Northern States the leading ones in manufacturing. Maryland can furnish, however, no examples of stream discordances resulting from either volcanic or glacial agencies. Several other causes of poorly adjusted streams might be mentioned, such as volcanic ash blankets, extensive loess and other alluvial deposits.

Having thus briefly reviewed the processes which control the topographic development of any area, we will now proceed to take up in particular the development of Maryland topography. The state, as remarked in a previous volume, may be divided into three general physiographic provinces, namely, the Coastal Plain, the Piedmont Plateau and the Appalachian Region. The boundaries of these provinces are represented on the map forming Plate III. To the consideration of each of these with their subdivisions separate chapters will be devoted, followed by a chapter in which special attention will be given to the Piedmont Plateau.

The Coastal Plain Province.

INTRODUCTION.

General Structure.

The eastern portion of the Atlantic Slope of North America, from Cape Cod to Florida and around the shores of the Gulf of Mexico, is bordered by a broad fringe of horizontally bedded deposits, extending from the Fall Line to the edge of the continental shelf, whose topographic characters and geological origin have won for it the name of the Coastal Plain. The researches of the stratigrapher and the paleontologist have unraveled the intricacies of the numerous beds which compose the Maryland area, and an account of their results is found in another place.[1] Here will be given only a brief sketch of those events in the history of the Coastal Plain which are most important from the geographical standpoint.

The Coastal Plain series begins with a group of formations, the Potomac Group, whose lithologic characters clearly indicate the conditions of the lands which they bordered. The lowest strata, Patuxent formation, composed of arkosic sands and clays, clearly show that the materials were derived from a deep mantle of disintegrated gneissic and phyllitic rocks such as that which now characterizes the surface of the Piedmont Plateau from Maryland southward. These beds everywhere rest upon the uneven surface of crystalline rocks which belong to the same series as those which constitute the Piedmont. This surface may, in fact, be traced as it passes out from beneath the sedimentary deposits and, bared of that covering, forms the rolling surface of the Piedmont Plateau of to-day. Detached portions of the sedimentary beds, as well as their general lithologic characters, indicate that they formerly extended farther westward than they do to-day. Their presence shows that hills now three or four hundred feet above sea-level once formed the ocean floor and were swept by waves, tides and currents.

Above the clays and arkose follow beds of clean white sands, and these again are overlain by lenses of iron-ore-bearing clays, Arundel formation, which were deposited in bogs that formed in depressions

[1] Maryland Geol. Survey, 1897, vol. i, p. 188 et seq.

of the older deposits. These depressions have the characters of old water-courses, and are interpreted as indicating a period of elevation above sea-level when the rains had opportunity to erode the surface of the earlier deposits. Interesting fossils in the shape of Dinosaurian skeletons found in these deposits show that great lizard-like creatures frequented the shores of the period.

Higher members of the Potomac group consist of variegated clays and coarse, irregularly bedded sands, Patapsco and Raritan formations. They are succeeded by sands and clays in alternating sequence, with slight variations in characters and progressing towards deposits of an argillaceous and finally glauconitic and marly character, Matawan, Monmouth, Rancocas and Pamunkey formations, which show that for some time true marine conditions prevailed in place of the shore conditions which produced the earliest formations. The transition from shore to deep-water conditions was preceded by a period of elevation during which a very considerable amount of erosion and valley-making went on. Smaller variations of level also took place from time to time and are recorded rather by the physical breaks and interruptions to deposition than by the lithological changes in the deposits.

Following the last period, the Pamunkey, which was characterized by deposits formed in moderately deep and quiet seas, came a period when the seas abounded in the microscopic plants called diatoms, and the deposits of this time are characterized by heavy accumulations of the siliceous skeletons of these small organisms. Following these came extensive deposits of clays and sands, crowded with infra-littoral organic remains, in which molluscan shells largely predominated. All of these deposits, representing several more or less clearly defined formations, are embraced in what is known as the Chesapeake Group. With the close of this period the deep-water history of this portion of the Coastal Plain ends. Elevation with landward dépression succeeded the Chesapeake, during which the rocks of Maryland were subjected to a period of decay. These land conditions again gave way to littoral conditions. As the coastal border gradually sank, the transgressing line of ocean breakers rapidly worked over the materials

already at hand in the older deposits and the decayed crystallines of the present eastern Piedmont belt. Thus was produced a sheet of gravels, sands and clays which spread out over the whole of the Coastal Plain province from Maryland southward to the Gulf.

The constituents of this formation, the Lafayette, change in character from one locality to another, and in many ways indicate that they were arranged by the restless waters of an ocean beach, thus distinguishing them from most of the earlier members of the series which, as already shown, have deep-water or estuarine characters.

Lafayette deposition was closed by an elevation which gradually elevated the Coastal Plain above the ocean, and enabled the Piedmont streams, not only to extend their courses eastward across the slowly emerging land surface, but also to cut deep gorges in the underlying strata. Besides the topographic record of the post-Lafayette emergence, evidence of the weathering influences of the atmosphere is not lacking in the general state of disintegration of the materials composing the formation.

Following the elevation and dissection of the Lafayette formation came a succession of depressions and elevations, accompanied in turn by deposition and denudation, that has produced a complicated history down to the present time. The deposits of this period have been described hitherto, so far as they have been recognized, as the Columbia formation, and appear at various elevations along the rivers, estuaries and inter-fluviatile districts of the Coastal Plain.

Professor R. D. Salisbury has published many interesting facts regarding the Coastal Plain gravels of New Jersey, and the investigations of the Maryland Geological Survey now in progress point to an early solution of the problems connected with the later history of the Coastal Plain in this state.

It appears, therefore, from what has been stated that the Coastal Plain is built up of a series of strata, for the most part composed of still unconsolidated materials arranged almost horizontally. Each successive sheet bears a portion of the geological and topographic record of the province, the whole showing that the land in this region has undergone many variations in altitude. Careful detailed

study and mapping of the individual earlier members of this series will in the future yield interesting results and give many additional facts concerning the past topographic history of the old land area lying beneath and west of the province, but at present no attempt will be made to consider more than the comparatively recent history and topographic changes which have taken place within the area. Therefore, confining ourselves to that portion of the Coastal Plain which lies within the boundaries of Maryland, the next section will set forth the limits and subdivisions of the province.

Boundaries and Subdivisions.

Before the post-Lafayette emergence, the Coastal Shelf or Coastal submarine Plain stretched from the unknown shore of those times eastward almost if not quite as far as the present edge of the continental shelf. We need not go back farther, however, for our present needs than to the middle of the Neocene, when the last extensive submergence took place. The exact extent of this submergence, during which the Lafayette formation was accumulated, is at present somewhat in doubt. Mr. A. Keith[1] has reported that remnants of this formation occur along the eastern foot of Catoctin mountain in Maryland and Virginia; but as the determination of the age of the deposit in those districts is based partly on lithologic characters and partly on the possibility of correlating certain topographic features of the western Piedmont Plateau with post-Lafayette formations in the Coastal Plain series, the date cannot be regarded as being definitely determined. Outliers of the Lafayette situated nearer the western boundary of the continuous strata, and of whose age there is no doubt, clearly show, however, that the submergence was very considerable in amount and in extent,[2] and that it was terminated by an uplift which raised the western portion of the coastal shelf higher above the sea-level than it stands to-day.

After the emergence, and as the result of it, the heretofore wholly

[1] A. Keith, "Geology of the Catoctin Belt," U. S. Geol. Surv., Fourteenth Ann. Rept., 1892-3, ii, p. 285.

[2] McGee, W J, "The Lafayette Formation," U. S. Geol. Surv., Twelfth Ann. Rept., 1890-1, i, pp. 508-511.

submerged Coastal Plain became divided into two great sections, which continue to the present time. These two sections were an eastern submerged portion, which will be referred to as the *submerged* or *submarine section*, and a western emergent portion, hereafter designated the *emerged* or *subaërial section*. The common boundary between these was the new shore line.

The term Coastal Plain as heretofore used by students of American geology has generally referred to that portion of the Coastal Plain which is called in this paper the subaërial section. Since the subaërial plain admits of comparatively easy investigation, because of the deep dissection it has undergone, and because it is habitable by Man, while the eastern submerged portion is wholly beyond our reach save through the revelations of the sections obtained from artesian well borings, very naturally our conception of the Coastal Plain has been bounded on the east by the Atlantic shore line. It is believed, however, that the proposed extension in the scope of the term Coastal Plain and its subdivision into a submarine and a subaërial portion is fully justified by the stratigraphy of the province and by the fundamental topographic form of the two divisions. To these two divisions of the Coastal Plain J. W. Powell[1] has added a third one, which is designated the *marsh portion*, recognizing as a separate subprovince that part of the plain "which is covered more or less intermittently with water by tides and storms."

The limits of the Coastal Plain, as thus newly defined, are on the east, the boundary of the coastal shelf, and on the west the intricately crenulate line which marks the boundary between the unconsolidated sands and clays of the Mesozoic and Cenozoic and the crystalline rocks of the Piedmont Plateau. West of this continuous boundary are scattered small detached areas, whose lithologic and stratigraphic characters show that they belong genetically to the Coastal Plain series, but have been separated from the main body by the activity of denuding processes since the province was raised above the sea-level.

[1] "The Physiography of the United States," 1896, p. 75.

SUBMARINE DIVISION.

Boundaries.

The submarine portion of the Coastal Plain may be considered as extending from the western shores of Sinepuxent and Chincoteague Bays eastward to the one hundred fathom line, which is very closely coincident with the eastern boundary of the continental shelf, and lies on the average about one hundred miles off shore.

The Sea Floor.

Viewed as a whole, the surface of the submarine division of the coastal plain is a broad, even surface, gently sloping seaward and swarming with animal life. It is the feeding ground of most of our valuable sea fish and, therefore, the chief cruising ground for fishermen. Upon closer examination the shelf is seen to be very mildly and irregularly undulating, the swells and troughs becoming fewer

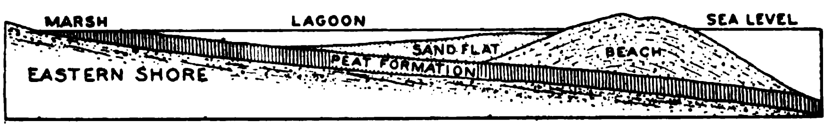


FIG. 10.—Section across off-shore beach and lagoon.

and milder seaward. These features are admirably shown on the U. S. Coast and Geodetic Survey charts.

Off-shore Beaches.

Shoreward the even surface of the submarine plain is broken by the narrow bank of sands, which forms the long barren stretch of Sinepuxent Beach. This beach, and the long shallow bay behind it, see Fig. 10, are of particular interest, because they furnish excellent home examples of a type of coast line which characterizes North America from Long Island to Southern Mexico. This type is found wherever there is strong on-shore wave action across a shallow coastal shelf. As the great swells come in from the Atlantic the depth to which their vibrations disturb the ocean waters approaches more and more closely the actual depth of the water over the shelf. Ultimately, the disturbances begin to act on the bottom. The waves thus meet with considerable resistance in their lower sections, due to

friction between the water particles and the sea floor. The result is that sand and mud are stirred up by the onward moving waves, and are carried shoreward with them until they break upon the beach. The breakers stir up still more sand by the impact of the mass of falling water. Many an unhappy bather who has had his mouth filled with the gritty water, as a wave, thus ladened, broke over him, will testify to its truth.

The sand stirred up by the waves and breakers is disposed of in several ways. Some of the material is carried along the shore by currents, much of it is thrown into a long heap or windrow landward, where the surf is breaking, and a portion is carried back to the deeper water by the undertow. The greatest advance in building beaches by such wave action is made by storm waves, whose greater power enables them to accomplish much in a short time. The great changes produced by storms are well recorded, because of their sudden appearance and often disastrous consequences to human interests, but although they are among the prime factors in producing coastal changes, they do not so strongly overbalance the less striking but long-continued activity of other agents. Important among the latter is the wind, which heaps the dry sands of the beach into dunes, thus insuring the stability of the beach as such above the water. A very considerable amount of sand is also blown into the lagoons which lie behind the off-shore beaches, thus materially aiding in the slow process of filling up those water bodies.

Outside the beaches and along the coast various marine currents are constantly at work distributing the sands which the waves and the undertow bring out from the beach or stir up from the bottom. These currents may be of tidal origin, set in motion by the daily ebb and flow of the great tidal wave, and would have their directions determined by the obliquity which the crest of the tidal wave[1] makes with the general direction of the coast line. Other tidal currents

[1] By *tidal wave* is here meant the broad wave of water which the attraction of the moon and other forces maintains upon the open ocean and draws after it as the earth turns upon its axis. The term should not be confused with the phenomenon popularly called a "tidal wave" which results from some volcanic explosion or seismic disturbance beneath the ocean and has nothing whatever to do with ordinary tidal phenomena.

with general off- and on-shore directions occur at the tidal inlets to the lagoons and sounds behind the beaches, where the inflowing and outflowing waters of the sounds have built bars and extensive shoals or tidal deltas.

The waves themselves, aided by the winds which drive them, set up the most important currents. As the waves run obliquely against a coast they set up a steady drifting of the water in the direction resultant from the direction of the coast and the direction in which the surges are moving. For example, if, as is the case on Maryland coasts, the heavy surges set up by a storm come rolling in from the east or northeast against a shore line whose general direction is southwest, the energy of those waves is partly expended in beating directly against the beaches, although a very considerable component turns along the shore in a southwesterly direction. In this way a southwest drift along shore is set up. Again, storms from the southeast, in a similar manner, set up a northeasterly drift or coast current.

These currents are well known to the fishermen and members of the Life Saving Service along our coasts. Their direction of flow may be detected by the drifting of wreckage during and after storms, and the average direction of drift during series of months and years is expressed in the general configurations of the beaches, capes, inlets and shoals. Along the Maryland and Virginia coast there seems to be an almost even balance between the two sets of currents. To the north, *i. e.* on the Maryland shores, the smooth beach shows but little by which to judge. The closing of an inlet into Sinepuxent Bay (see below, p. 83), and the recent opening of a shallow one to the south, across the beach into Chincoteague Bay, are in favor of a southerly current. So also is the general configuration of Assateague Island and its apex at Fishing Point, while the general direction of the shoals and bars off Cape Charles indicate that a decided current from the north brings down the sands which are drifting around the Cape into the mouth of Chesapeake Bay.

On the other hand, the position and direction of the banks and bars of the Chincoteague, Black Fish, Winter Quarter, Isle of Wight and Fenwick Shoals and the forms of the beaches on the east side

of the Eastern Shore of Virginia point very decidedly towards the presence of a current setting from the south or the southwest.

Coastal Lagoons.

Behind the low sandy beaches along the Atlantic coast of Maryland are imprisoned shallow lagoons somewhat similar to those of the New Jersey coast. These bays, though having different names in different parts, Sinepuxent, Isle of Wight and Chincoteague Bays, are nevertheless all one body of water. The width is very variable, ranging between half a mile at Ocean City to four or five miles at the wider portions. The shores of the lagoon are formed on the east by shallow marshes along the western edges of the outside sandy beaches, and on the west by the low, half-submerged topography of the mainland, somewhat modified by the salt marshes, which have attained considerable size at some points.

The floor of the lagoon is very shallow and flat, and largely composed of sand, which blows over from the dunes along the beaches, of mud and, near the western shore, of matted roots, which really form the foundation for the overlying sands.

The deepest portions of the bays are found along the western side, next to the mainland, and even in these spots the depth does not exceed seven or eight feet. Over most of the bay the depth is from one to three feet, so that the waters can be navigated only by boats of very shallow draught. The reason that the channel, as the zone of deepest water is called, is uniformly located so far towards one side, and that the western one, is, that the easterly storms, and indeed every brisk wind, blow quantities of sand from the dry dunes of the beach across into the bay. Thus a sandy shoal, now only one or two feet below the level of high water, has been built just in the lee of the barrier beach. Eight or ten rods in the width of this shoal have been so far built up, that it is now a brackish marsh overgrown with coarse salt grass, and much of it is firm enough to tread on without sinking. Beyond this naturally reclaimed portion the shallow sandy bottom is steadily encroaching year by year upon the formerly deeper waters of the bay. At the same time the marshy western shores of the lagoon are being slowly consumed by the attacks of

the waves which arise in the shoal waters of the bay, although no accurate estimate of the rate of recession can be given.

The currents and the position of the water level in Sinepuxent and Isle of Wight bays are not influenced at all by the tides, and very little, if at all, in Chincoteague Bay, except in the immediate vicinity of Chincoteague Inlet. All the important currents are controlled entirely, both as to their directions and force, by the winds and configuration of the bay shores. When a brisk north or northeast breeze is blowing the waters are driven southward, thus setting up a current in that direction and tending to cause low water in the upper end of the bay, while a southerly wind may at another hour of the same day wholly change matters and heap up the waters at the north end of the bay.

The waters of these shallow lagoons do not communicate with the ocean except through Chincoteague Inlet and a small break in the long cordon of sandy beach that was recently made a few miles south of Ocean City during a severe storm. Up and down the whole length of the Maryland shore there are but these two inlets to the land-bound waters, one being very small and unimportant. This condition is not typical for such bays or lagoons as are found on the coasts of New Jersey and the Carolinas. It is more usual to find inlets interrupting the even stretches of sandy beach at several points, forming gates to the sounds similar to Barnegat Inlet of the New Jersey coast or Topsail Inlet of the Carolina coast. Such inlets, however, are of uncertain duration, and several along the Carolina shores are known to have been closed completely, as the result of the washing in of sand during great storms. Other inlets, formerly deep enough to admit sea-going vessels at low tide, are now so shallow that entrance is completely barred. It appears that one or two such inlets at one time cut across the long sandy reaches of Sinepuxent beach.

J. T. Ducatel[1] states in his Annual Report for 1835, that: "It is an interesting fact connected with the past and present condition of Sinepuxent sound that, since the closing up of some inlets admitting

[1] Ducatel, J. T., and Alexander, J. H., Rept. on the New Map of Maryland, 1835, p. 52.

the ocean into it, its waters having thus become comparatively fresh, the oysters and clams, by which they were formerly thickly inhabited, have died, leaving extensive beds of their exuviæ." The former abundance of these shell-fish in the sound is also evidenced by the Indian shell heaps found on Sinepuxent neck, proving that the Indians of the vicinity resorted to the sound for their supply of oysters. This change in the saltness of the water of the sound is an interesting illustration of the control exerted by geological conditions in changing the lives and habits of men. Prior to the storm, or series of storms, which closed the inlets, the thriving oyster beds attracted the aborigines and furnished them with a much prized article of food; now the nearly fresh waters of the same sound no longer support the finer grade of salt water oysters, and to obtain them we must search farther south in the vicinity of Chincoteague Island where the ocean waters still reach.

SUBAËRIAL DIVISION.

Boundaries.

The subaërial division of the Maryland Coastal Plain extends from the western shores of Chincoteague and Sinepuxent Bays to the western boundary of the province. It will be regarded as embracing the so-called "tidewater" section of the state with its many navigable streams and that old river valley, the Chesapeake Bay, which, from earliest times, has been the leading highway of traffic in Maryland.

General Topography.

Passing from the submarine to the subaërial division of the Coastal Plain, there is no sudden change in general topographic features. The surface of an area newly arisen above the sea, where it had long been the seat of deposition, would naturally possess the predominant characteristics of the sea floor. One prominent feature is the broad, even plain, once the smooth or gently undulating sea bottom. The relatively new land surface of this division possesses this character in a very marked degree, and is typically illustrated by Plate VII, Fig. 2. Many portions of the Eastern Shore of Maryland are characterized by long interstream stretches of considerable breadth that

are almost plane surfaces, and the same is true of several areas on the Western Shore in the peninsula of Southern Maryland. Taken as a whole, the Subaërial Division is quite as flat as the Submarine Division, although considerable depressions, particularly in its western portions, due to stream erosion, cause many interruptions in the continuity of the plain.

FIG. 11.—Piedmont Plateau partially submerged.

Another feature generally belonging to emerged marine plains, and characteristic of that portion of Maryland's Coastal Plain which falls under this class of land forms, is the gentle and uniform seaward inclination of the general surface. This is admirably shown by the hypsometric map forming Plate VI of Volume I, 1897, of the reports of the State Geological Survey. As may be seen from this map, the general slope of the Eastern and Western Shores of Maryland is towards the southeast, the rate of decline being about three

feet per mile for the counties of Southern Maryland and rarely more than one and a half feet per mile over the eastern counties of Kent, Queen Anne's, Caroline and Talbot.

Drainage Pattern.

Besides the general features of the province and the gentle seaward slope of its surface, the drainage pattern, which is the direct product of these two factors combined with the general homogeneity of the strata, is characteristic and typical for the area. This stream pattern is irregularly branching or dendritic. The smaller streams in most cases make approximately a right angle with the general course of the larger streams, where they join the latter, but the larger waterways do not obey the laws which govern drainage development under the simple conditions of a Coastal Plain, although the courses of the main stream, it is true, are approximately parallel with one another and enter the bay or ocean at right angles to the shore line which they intersect. Most of the streams, however, depart from the type in that they do not traverse the width of the Coastal Plain's subaërial portion from the old land to the Atlantic, but generally flow from either side down into Chesapeake Bay. This abnormality of the streams will perhaps be more easily understood if the stages in the development of drainage on an emerging Coastal Plain are briefly reviewed.

General Drainage Development.

Starting with the epoch when the western portion of the Coastal Plain began to appear above the sea, it is evident that, as the land rose and the waters receded eastward from their old bounds, the rivers flowing from the older land area or the Piedmont Plateau would gradually extend their courses across the new land, keeping their mouths at the new shore line. This advance of the lower courses of the old streams would keep pace with the retreat of the coast line, and the direction of the new lower courses would be determined both by the slope and the inequalities of the new surface over which they passed. In the normal course of events, therefore, these extended streams should enter the ocean by courses approximately at right

angles to the general direction of the coast line, as shown in Fig. 12. This is to be more confidently looked for in the case of those streams whose volume and size would enable them to easily overcome the slight obstacles which the generally smooth surface of an emerged marine plain might offer to such a course. Such is the case with the Chattahoochee, the Tombigbee, the Savannah, the Santee, and num-

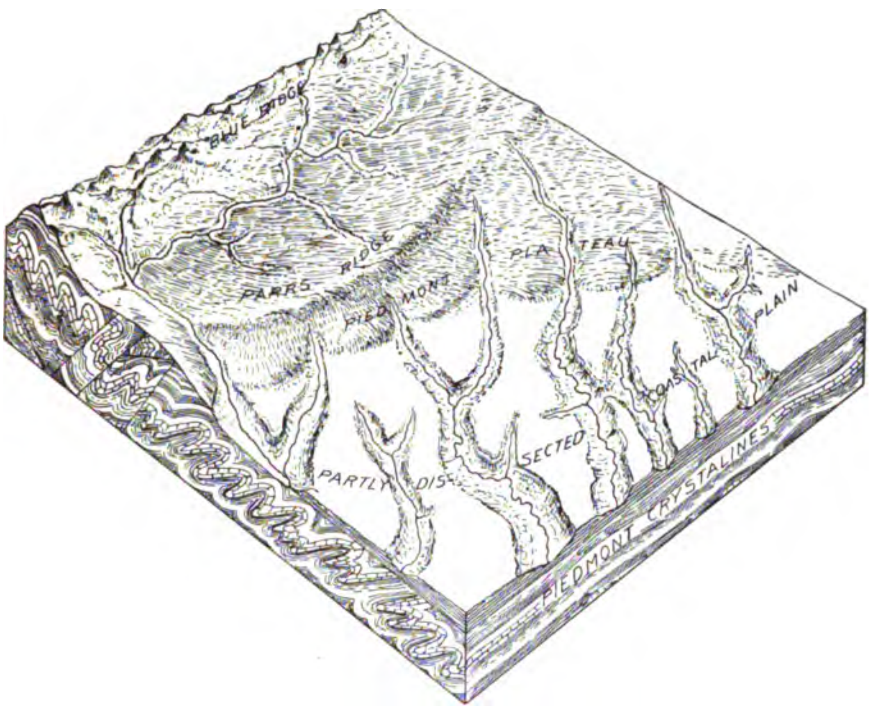


FIG. 12.—Piedmont Plateau and Coastal Plain elevated.

bers of others which cross the southern Coastal Plain from the old land to the sea. It is therefore surprising to find that large, powerful rivers, such as the Potomac, the Susquehanna and the Delaware, which have successfully crossed many resistant strata in the Appalachian district, turn aside on reaching the incoherent beds of the Coastal Plain and pursue such roundabout routes before they finally reach the Atlantic.

While the streams of the old land are thus actively extending their courses and reducing their channels to a suitable grade, another class of streams have come into existence. The rain which falls upon the surface of the newly-born land is partly drained into the extended lower courses of the preëxisting rivers, but it also happens that a large share of the drainage is effected by streams which originate upon the Coastal Plain itself independently of the extended rivers. These streams, which arise independently of former drainage lines of any sort, are guided in their development only by the character of the strata and the initial inequalities, large or small, which they find on the surface of the new land. As the general inclination of the surface is seaward, and they are acting almost wholly under the influence of gravity, their courses are taken as nearly as possible along the lines of steepest slope, generally at right angles to the coast line.

If the land continues to rise these new streams also will extend their lower courses to keep pace with the receding shore line. At the same time their headwaters are being extended by the gnawing back of the ravines which characterize stream heads and by the development of new ravines. These new ravines start upon the side slopes of the old ones, and as there is no important variation in the amount of resistance offered by the various strata, whereby any control could be exerted upon the direction of growth of the new ravines from which they start, all have equal chances for development. A ravine once started tends to keep on in the same direction, as may be observed in the case of the small ravines and gullies developing along bare hillsides. The result of this mode of development is the growth of a more or less intricately and irregularly but systematically ramified drainage system of dendritic pattern, which has come to be recognized as typical for the drainage developed upon newly exposed plains of subaqueous origin. Smaller streams of the same type may also develop in regions whose main drainage lines are under control of other factors, such as tilting or folding. In these cases the subordinate or tributary streams only will belong to the type under consideration. This is an important fact, as it will appear that to

THE HELIOTYPE PRINTING CO. BOSTON

ELK AND BOHEMIA RIVERS, FROM ELK NECK.

AT THE HEAD OF CHESAPEAKE BAY.

this second category belong the majority of the streams of the Coastal Plain in Maryland. This general stream pattern has been designated by McGee[1] as *autogenous*.

During the earliest stages in the drainage development of an emergent coastal plain, small lakes and swamps may dot the surface of the new land in greater or lesser numbers. They would arise from the accumulation of rain-water in the original inequalities of the surface. Such inequalities on the sea bottom are produced by the actions of waves and currents which do not always distribute sediments in a perfectly even manner. This is very well shown by the character of the sea floor along the present Maryland coast. The lakes or swamps, due to accumulation of water in such hollows, should disappear early in the course of drainage development. Their outlets generally admit of rapid cutting down, so that the waters are soon drained off. Thus lakes of this origin, characterizing only the earliest or *Infantile* to *Adolescent* stages in topographic development, when present, give a clue to the topographic age of the area.

The ideal scheme of Coastal Plain drainage as outlined above is interrupted by the southwestward prolongation of the Susquehanna river in the expanse of Chesapeake Bay, which divides the Subaërial Section into the Eastern Shore and the Western Shore of Southern Maryland.

THE EASTERN SHORE.

The Eastern Shore of Maryland occupies a large part of the peninsular Coastal Plain between Delaware Bay, the Atlantic Ocean and Chesapeake Bay. This topographic subprovince also includes most of Delaware and the Eastern Shore of Virginia.

Relief.

The peninsula has but slight altitude, rarely reaching a maximum elevation of one hundred feet even in the higher northern counties, and declining gradually southwards to a mean elevation of about twenty-five feet in Somerset and Worcester counties. Besides the broad open valleys of the larger streams and the flat interstream

[1] McGee, W J, U. S. Geol. Surv., Eighth Ann. Rept., 1885-86, pp. 561 et seq.

areas, the only topographic feature of prime importance is the broad height of land which forms the divide between the eastward and westward flowing streams. At this point it is enough to indicate that its distance from the Atlantic or from Delaware Bay rarely exceeds fifteen or twenty miles, while it generally lies from thirty to forty miles east of the eastern shore of Chesapeake Bay and just north of Berlin, Maryland, is sixty miles distant. The high land extends south-southeast from Elk river, keeping approximately parallel to the eastern shore of the peninsula as far as the headwaters of the Pocomoke river. It then turns to the south-southwest, following the Atlantic coast line in a sympathetic curve down the lower portion of the Eastern Shore of Virginia, gradually decreasing in elevation until it merges into the low-lying lands north of Cape Charles.

Stream Characteristics.

The Eastern Shore is on the average fairly well supplied with streams, the majority of which drain southwestward into the Chesapeake. All the large streams, following more or less tortuous courses, flow into the Bay, and most of the smaller streams have courses roughly parallel to the larger ones. Only small streams, generally insignificant in size and comparatively few in number, drain eastward into the lagoons lying behind the off-shore beaches and bars of the Atlantic coast.

All the streams fall into one or the other of two classes. They either lie wholly upon the general surface of the country, are small in volume, not navigable, except where dammed, and do not reach directly to tidewater, or they reach tidewater and the larger ones are navigable at least by small boats for some portion of their length. The streams belonging to the first class are characterized by broad, shallow valleys, with very gentle side slopes, which are not seamed by rill-channels, but present smooth, rounded or even plane contours. Generally there is some alluvium collected along the stream channels, but as a topographic feature these flood-plains are usually difficult to distinguish from the mild side slopes of the valleys. In the northern portion of the Eastern Shore peninsula, where the general altitude is highest, the streams have more sharply defined valleys,

and are, in general, more actively engaged in working over the materials of their flood-plains. Contrasted with this section, are the streams of the inter-estuarine areas in the southern counties. There one may travel for miles and never cross a well-marked channel. Where the forests have been allowed to remain, they have so far prevented evaporation that the swamps which formed in original surface inequalities retain a considerable amount of moisture, even through the hot summer months, and sometimes little rivulets may be found in close proximity to these forested areas. As a rule, however, the configuration of the surface betrays no sign of stream sculpture, but seems to have received its outlines wholly from the waves and currents of the ocean during its last period of submergence. It is in the middle counties—Talbot, Caroline and Dorchester—that the streams approach more nearly the typical inland drainage of a recently emerged marine plain. In these counties the stream characters correspond closely to the general description given above.

The streams whose lower courses merge into tidal estuaries belong to the second class of Eastern Shore Coastal Plain streams. The headwaters of nearly all the members of this class belong to the first class of streams, and present the characters which have been described. The transition in these streams from the shallow alluvium-lined valleys of the above-tide district to the free and open estuarine division is not a sudden one. Between the two extremes lies a stretch of river whose waters ebb and flow with the tide, but whose steep banks are deeply fringed by reed-covered marshes. This transition is most clearly and beautifully illustrated by the Choptank river, which may be taken as the type. The same features are shown almost equally well by the Nanticoke, the Wicomico, and the Chester rivers.

The lower course of the Choptank is an open bay about six miles wide in its broadest part, so that in spite of the comparatively shallow waters (off Cook's Point there is a maximum depth of ten and one-quarter fathoms) strong winds or sudden storms in summer always set a heavy sea running. The shores are low, rarely rising twenty feet above tide, and intricately dissected by small tidewater creeks, par-

ticularly along the peninsular area between the Choptank and Eastern Bay. The banks facing the channel do not slope down gently to the shore, except in those cases where the land stands lowest and is in a protected bay. Usually they form sharply-cut cliffs of varying height. These cliffs, fashioned by the waves which often arise on the river, are best developed along the exposed stretches of shore, and are in every instance accompanied by some form of spit or bar stretching to leeward, and built of the waste cut away by the waves. Already in this lower course of the river, the small creeks emptying into it are found to be shoaling and silting up their channels, as a result of the sand-bars and beaches which obstruct their mouths. Proceeding up the river, however, the marshlands, which have been confined to creeks and lagoons below, begin to encroach on the open waters of the channel. The sharp points, unlike their congeners downstream, do not have off-shore extensions in the shape of sandy shoals or spits, but have developed marshy accumulations of sand and alluvium firmly woven together and held by a mass of matted grass roots. For a short distance these marshes are confined to the stream mouths, and the points, while having intermediate stretches along the shore, are undercut, forming cliffs. These cliffs can often be traced along behind the marsh-formed outlines of the points and bays. Above Secretary creek the marshes increase in area so greatly that the bounds of the channel are formed almost wholly of those accumulations. The tortuous stream grows narrower as the marshes widen, and swings in broad meanders, sometimes cutting directly against the steep banks of the stream, when a strong bend carries the current sharply to one side or the other.

Back of the marshy ground the banks of the river appear as steep cliffs, which are now well wooded, and thus protect the banks from the attacks of the rain and the wind. These steep wooded banks present a decided contrast to the generally less precipitous slopes which border the small tidewater confluents of the Choptank, and they clearly form sudden interruptions in the broad, gently rolling surface of the interstream areas. The boundaries between the firm land of the Coastal Plain and the tidal marshes, as expressed topographically

by these low bluffs, are clearly designated on the U. S. Coast and Geodetic Survey Chart No. 135. This chart conveniently sums up for general study the tidewater details of the river system, and shows even better than one can see the facts on the ground, the gradual encroachment of the marshes and the line of low bluffs behind them. It is very clear from this map that the original banks of the river, up to the head of navigation and beyond, are represented by these marsh-bound cliffs. Apparently the earlier channel, which the river followed before it had built the marshy flood-plains, was much more direct than it is to-day. Some allowance, however, must be made for the straightening of the banks under the action of the waves in earlier times, such as is now going on farther down-stream. At the present time, also, there is some straightening done by the cutting of the stream where its channel is turned against the higher bluffs at the apex of some meander.

Above tidewater a marked change comes over the valley. Instead of strong tidal currents, which by their scour keep open a narrow pathway, the channel is occupied by a small stream, which is unable to carry away all the waste washed into it from the valley slopes. These slopes, also, while maintaining their steep faces for a short distance, rapidly give way to the milder slopes and open valleys of the interior. The flood-plain, which characterizes the stream in its non-tidal portion, is clearly continuous with the growing marshes of the tidewater district.

On comparing the other large streams of the Eastern Shore with the Choptank, they are found to depart but slightly from the characteristics of that stream. What variations occur, relate chiefly to the shores of the estuarine portion, and are discussed below under the head of Shore Features.

The streams flowing eastward into the coastal lagoons of the Atlantic shore have already been briefly touched upon. They are, in Maryland, small and insignificant runs, flowing over marshy bottomlands. The largest is St. Martin's river, emptying into Isle of Wight Bay, and next in size is Trappe creek, which flows southeastward from Trappe, near Berlin. Although so insignificant in Maryland, this At-

lantic drainage attains a somewhat greater, although still very moderate, development in Delaware, where it numbers among its principal streams Indian river, Broad Kill, Mispillion creek, Motherkill or Murderkill creek, Appoquinimink creek and Christiania creek. The topography along the lagoons of Maryland and behind the off-shore beaches on Delaware Bay clearly shows that these creeks, even the smaller ones, belong to the class of streams known as "drowned." That is to say, after having established themselves upon the new land surface, and cut out characteristic valleys, a slight subsidence has allowed the sea waters to penetrate inland, overflowing and drowning the lowest portions of their valleys. The larger streams of St. Martin's river and Indian river have, with the Pocomoke and Nanticoke rivers, common sources in the Great Cypress Swamp which covers such a large area in Sussex county, Delaware and Wicomico county, Maryland.

This swamp is particularly interesting because of its position on the great Atlantic-Chesapeake divide discussed below. It has been pointed out that one of the characteristic features of the ideal drainage of a newly emerged Coastal Plain is the formation of lakes, swamps, morasses, etc., in the original inequalities of the new surface. There are along the Atlantic seaboard several examples of such swamps, and particularly are they found in Florida, Virginia, Maryland and New Jersey, including the Everglades, the Great Dismal Swamp of Carolina-Virginia, the Great Cypress Swamp of Maryland-Delaware, and numerous small swampy districts along the Atlantic-Delaware river divide of the Coastal Plain in New Jersey. In all these cases there are two reasons why the swampy districts have not been drained. First, they are formed in inequalities produced by a submergence which took place in very recent geologic time, namely, the Pleistocene epoch. These districts seem to have been the last to come above the sea, even at that late date, so that there has been but little time for streams to do much active cutting. Moreover, it is to be noted that these swamps are located chiefly along main divides, suggesting that the streams which sprang up during the first period of post-Pleistocene emergence were able to drain swamps which were

located nearer the shore line, but have not as yet found time or strength to draw off the waters confined by the inequalities of the main divides.

Atlantic-Chesapeake Divide.

The peculiarly swampy character of this divide and its unsymmetrical location on the peninsula between the Atlantic and Chesapeake Bay are facts which distinguish it, when compared with the more usual characters of stream divides, and the laws which control their development.

It has been pointed out, in discussing the origin of the Coastal Plain province, that streams whose courses were extended across its subaërial portion or originated thereon would normally flow eastward and southeastward into the Atlantic. Thus the divides crossing the Coastal Plain would have been parallel to the streams and approximately at right angles to the shore line. How then can the present arrangement of drainage lines on the Eastern Shore be accounted for? In studying the development of stream divides it has been found to be a general rule that when the streams on one side of a watershed have a greater development than their opponents on the other side, their superiority may be traced to one of two causes. Either some original characters of the country gave to one system long courses and to the other short ones, or some features in the district subsequently revealed in the course of continued development have combined to aid one set of streams, while not offering equal advantages to the others.

There is no apparent reason for the unsymmetrical location of the divide in question, when the normal development of the Coastal Plain is examined for an original cause. The whole history of the Coastal Plain, so far as it is recorded in its earlier sedimentary deposits, would go to show that the streams ought not to be abnormal in any particular. Neither can there be found any traces of factors which, appearing after the streams had begun to develop, would be able to influence them in such a marked manner. A common factor of this latter class which in many parts of the country has played an important rôle is a heavy or very resistant stratum of rock. Such a stratum, by retarding the development of the streams compelled to

flow over it, gives the other streams, not so hindered, an opportunity to advance their headwaters and to reduce their channels more rapidly to a gentle slope. But no stratum of sufficiently contrasted resistance to produce such an effect can be found in the series of Coastal Plain strata within the boundaries of Maryland. If the indurated clays and sands of the Lafayette Formation be appealed to as sufficiently resistant to have such an effect on the streams the results produced would be just the opposite of those observed. The westward-flowing streams would first have encountered the opposition of the eastward dipping beds of the Lafayette, while the eastward-flowing streams of the Atlantic, having their courses down the dip, would have been last influenced by such opposition. The result then would have been that the Atlantic drainage would have developed at the expense of the Chesapeake streams, and the divide would now stand nearer the bay than the ocean.

Again, in a district of comparatively uniform and homogeneous lithologic structure such as the Coastal Plain, it might easily happen that one portion, receiving a heavier average rainfall, should therefore develop a stronger drainage system. The maps of average Annual Precipitation in Maryland and Delaware, published in the report of the Maryland State Weather Service for 1892-3, show the heavier rainfall to have occurred within the catchment basins of the Choptank streams, while the maps for 1894-5 show a slightly greater fall for the Atlantic streams in the same latitude. There are no strongly marked topographic features of the Eastern Shore which exert any control over the distribution of rain, and it is probably fair to conclude that the average of a number of years would show that there is a pretty even and equable distribution of rain to either district.

Shore Lines.

The most striking feature of the Eastern Shore, next to its extreme flatness, is the very intricate character of its western shore line. At first sight the meandering outlines appear to be a maze of creeks and coves without plan or system, and certainly the stranger, who tries to find his way about the multitude of creeks along Kent Island and Eastern Bay at the mouth of St. Michael's river or in Bay Hun-

dred at the entrance to the Choptank, would soon become confused by the great number of closely similar creeks and minor estuaries which are found there. These intricacies all work out very simply, however, by tracing out certain lines which may be found more or less clearly marked in nearly every cove and bay.

If, on one of the U. S. Coast and Geodetic Survey Charts of Chesapeake Bay, lines be drawn along the channels of the principal streamways, a pattern will be produced resembling so many bare trees, very crooked as to their trunks, and stripped of all except the largest limbs. The roots of these river trees lie in Chesapeake Bay, and their tops, merging into the surface streams of the province, lie against the great divide.[1] Tracing out the channels of all the little tide-creeks and bays, it will be found that many of the channel lines join or branch from the main stem and major branches, thus forming the subordinate branches and twigs of the "trees." Several smaller independent systems, such as the Little Choptank, Eastern Bay and St. Michael's rivers, which spring directly from Chesapeake Bay, will also develop.

If now these "trees" be compared with the branching patterns of most streams, for example, of such a river as the Patapsco of the Piedmont Plateau or the Patuxent of the Piedmont and western Coastal Plain, a striking similarity in the systematic irregularity of the branching at once appears. From such a comparison it is but a step to the conclusion that running streams of fresh water once carved out the channels which are now filled with the brackish waters of Chesapeake or Isle of Wight Bays. An elevation of one hundred feet would be sufficient to convert all these irregularities of coast line into a corresponding multitude of larger and smaller creeks which would empty into a great tidal river along the main channel of Chesapeake Bay. A depression of less than half this amount would convert all the rivers of Dorchester, Somerset, Wicomico and Worcester counties into such tidal creeks as are now found along their shores, and to a less extent would affect in a similar way the present streams of the more northern counties. Chesapeake Bay and its

[1] See Russell, I. C., "Rivers of North America," Fig. 22, p. 219.

tributary bays and rivers thus belong to that great class of streams called *drowned rivers,* and the coastal topography of the whole Coastal Plain of Maryland is for a similar reason to be classed as *drowned topography.*

Drowned topography and drowned rivers are not peculiar to Maryland, however, nor even to the Coastal Plain, although they are excellently illustrated in these districts. The numerous islands and deeply land-locked harbors along the New England coast, particularly in the state of Maine, afford beautiful examples of the same kind of coastal features, while the beautiful friths of Scotland and the famous fjords of Scandinavia and Finland are world-renowned examples of this class of land forms.

Since the drowning of the streams, the resultant expansion of the water areas in the valleys thus affected, and the introduction of tidal currents, have brought new forces into action which influence the development of shore topography along the streams. In describing the lower course of the Choptank, mention has been made of the wave-cut cliffs and wave- and tide-built bars and spits, which now distinguish the estuarine portions of that stream.

All these features are developed to a greater or lesser extent in the other rivers. The best development of wave-cut cliffs is found along the Sassafras and Chester rivers, where wide expanse of water is combined with high banks. The waves generated by the severe southeast and southwest storms, although raised in comparatively shallow waters, are forceful enough to undercut and bring down great masses of the indurated fossiliferous sands and marls. These blocks lie quietly on the shoal beaches during the numerous small storms of summer, but in winter are rapidly broken up and distributed along the shores. As a result of this continual supply of new material from neighboring cliffs, waves are building sand bars across the mouths of the smaller creeks, and as a result of this damming they are gradually filling up.

The tide flowing in and out of the rivers twice a day is also a factor and an important one in fashioning the outline of the river's shores. Several shore forms in the Choptank have been described

and attributed mainly to wave work. The side-currents or eddies set up between the shore and the main tidal current in the channel generally play an important and sometimes a controlling part in the building of the spits and bars which characterize the shores. The manner in which these tidal eddies work has been recently worked out by Dr. F. P. Gulliver[1] for a much larger estuary on the coast of the state of Washington, and Fig. 13 is designed to illustrate the arrangement of such eddies during flood tide. No special studies have yet been made of the many admirable shore features which the rivers of the Coastal Plain exhibit, but while working on the areal geology of the Eastern Shore I was able to note that in at least one case eddies

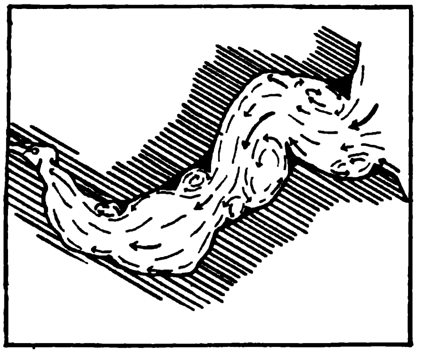


FIG. 13.—Scheme of Flood-tide Eddies in an Estuary (after Gulliver).

set up by the tide had influenced the growth of a cusp on the Sassafras, and it is very probable that tidal currents have also been influential in determining the growth of two sandy points on the Choptank.

The example in the Sassafras river is found at a point on the south bank of the river a short distance below Ordinary Point, which is itself probably, in part at least, the result of similar eddies. One day while endeavoring to tack down stream my companion and I found that we could make very little headway as we approached the south shore at this point, although when out in midchannel the strong ebb tide helped us along very nicely. On looking over the

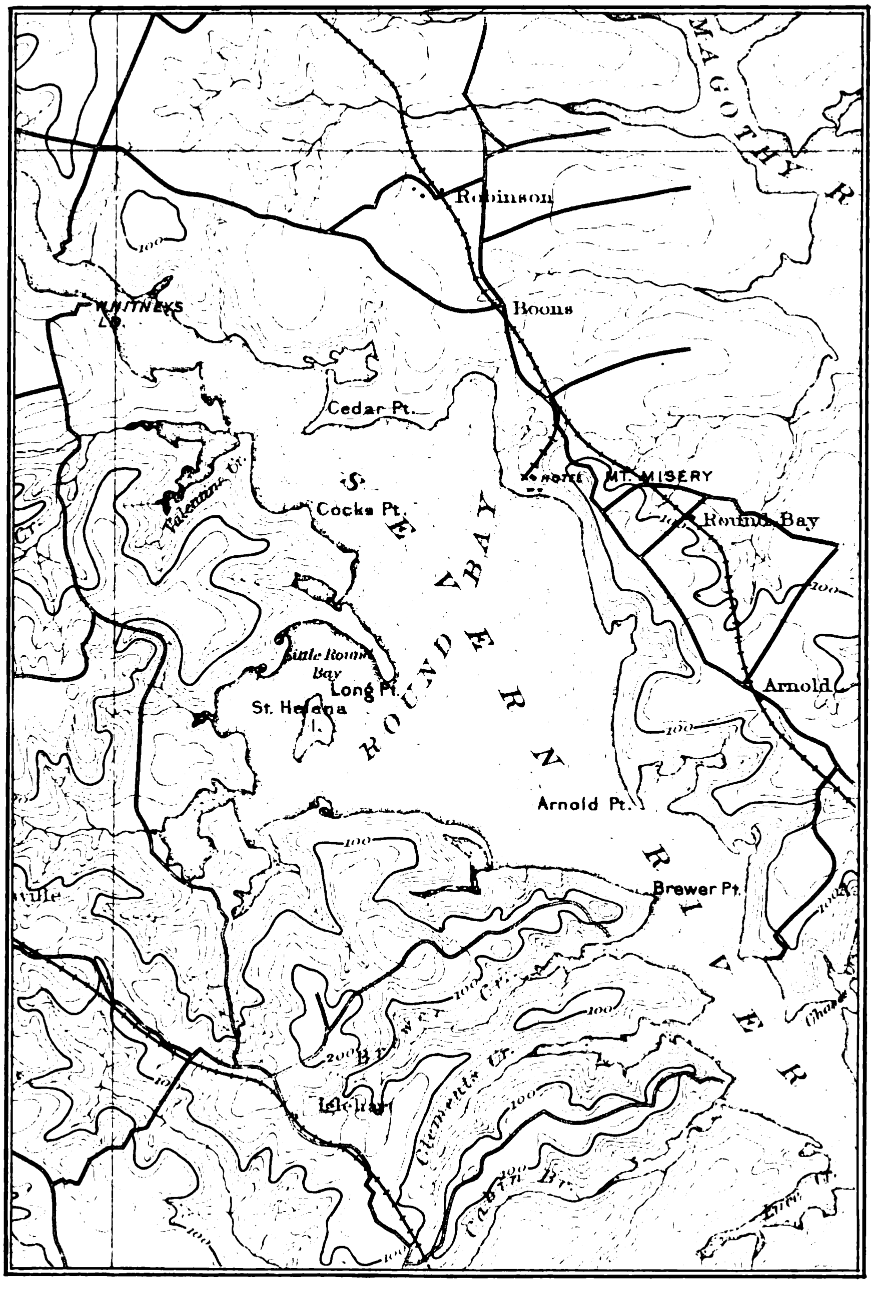
[1] Gulliver, F. P., Bull. Geol. Soc. Amer., vol. vii, pp. 411-41, Fig. 7.

side of the boat I saw that the waving eel-grass which grew in the shallow water near the shore was turned up-stream by a steady current of some strength. Evidently here there was a back-set eddy given off by the channel current, and conforming in its course to the smooth curve of the sand and gravel beach whose outline it had been instrumental in determining.

On the same river the long sandy spit known as Ordinary Point has been built up by the combined forces of tidal currents and the southwest winds, which set up strong waves, particularly in the broader portions of the lower river. The waves beating against the sandy cliffs on the northern bank of the river have washed out great quantities of sand, which the shore currents have carried up-stream, until, being deflected out towards the channel by a low point of land, they were there opposed by the tidal currents and forced to drop the sand which they carried. The tide acting regularly twice a day overbalances the less regular action of the strong waves, and has now stopped the further growth of the bar across the channel, by turning the tip down-stream, so that its further growth is opposed by the very waves which serve to build the bar outwards.

Besides these constructive and destructive changes which are taking place within the smaller estuaries, the islands at the mouths of the rivers seem to be gradually wearing away. The low swampy islands which characterize the Chesapeake border of the Eastern Shore are reported to have been firm, dry lands twenty-five years ago. Certainly now many fine trees which once flourished on them are being killed by the salt water penetrating to their roots. In many places, for example along the exposed portion of Kent Island, it is found that marshes formerly protected by and formed behind sandy beaches are now exposed directly to the beat of the waves and are being rapidly cut away, leaving a bench of soggy and matted roots about two feet below the mean tide level. Many years ago Ducatel[1] reported that the mouth of the estuarine portion of Pocomoke river and sound were filling so steadily with detritus and fine mud that it was not practicable to keep a ship-channel open there as an approach

[1] Ducatel, J. T., and Alexander, J. H., Report on the New Map of Maryland, 1835, p. 49.



MAP SHOWING COASTAL PLAIN TOPOGRAPHY OF ANNE ARUNDEL COUNTY.

FROM RELAY SHEET, U. S. G. S.

to a ship canal. It is also significant that the upper portion of the Wicomico river must be annually dredged out and the banks held back by posts and planking for the distance of a mile or so below Salisbury in order that the ship-channel may be kept free from the considerable amount of sand and mud which washes down from the surrounding banks.

These phenomena of washing away in certain portions seem to be contradictory, for the filling up of the streams does not occur at points where it can be related to the washing and wasting of the banks and cliffs before the attack of the waves. The washing away of the cliffs is chiefly confined to the districts in the vicinity and along the shores of Chesapeake Bay, except for the great flats which are growing in Pocomoke sound, while the filling is going on near the heads of navigation of the tidal streams. The rapid cutting which is going on along the western shore of the Chesapeake is interpreted by McGee[1] as an indication that the Coastal Plain is now subsiding, since only by steady subsidence can such continued wasting of the cliffs without contemporaneous shoaling of the adjacent shallow waters be accounted for. The steady filling in of the Eastern Shore streams of the tidewater province must either indicate a tilting, whereby the eastern portion of the Coastal Plain is being slowly raised and the bay portion depressed, or else the phenomenon directly contradicts the above conclusion, and the fact that Chesapeake Bay does not shallow more rapidly is to be explained by supposing that the original depth of the bay was greater than has heretofore been considered as probable. A consideration of the estuaries on the peninsula of Southern Maryland may offer a solution to this problem.

THE WESTERN SHORE.

The streams of that portion of the subaërial Coastal Plain which forms the peninsula of Southern Maryland or the Western Shore all belong to Chesapeake Bay drainage. There are but two or three large rivers which can be properly regarded as coming within the boundaries of this section, namely, the Potomac, the Patuxent and

[1] McGee, W. J., U. S. Geol. Survey, Seventh Ann. Rept., p. 618.

possibly the Susquehanna. All three of these streams have very considerable portions of their courses located upon the crystalline and the non-metamorphic formations of Western and Central Maryland or Pennsylvania, while only the lower portions of their courses cross the western portion of the Coastal Plain. All the other streams of the area rise within the boundaries of the Coastal Plain, so that their courses lie wholly within the province, and their origin upon the surface of the plain is obvious. The history of the three streams first mentioned is less evident. The Potomac and the Susquehanna which head far back in the Alleghanies and assumed the upper portion of their courses long before the Lafayette (Pliocene) submergence, undoubtedly belong to that class of streams already described which extended their lower courses seaward from the old land across the emerging plain. The Patuxent, judging from the present geological map of Maryland, would also seem to belong to this class of extended rivers. It is believed, however, from studies of the neighboring and related streams of the Piedmont Plateau, as well the features of its headwaters, that this stream, together with the Gunpowder and several others, originated on a former western extension of the Coastal Plain, all sedimentary records of which have been removed by subsequent erosion.

The streams of the Western Shore when compared with those of the Eastern Shore present considerable similarity in general features such as the drainage pattern, drowning and terracing. In several respects these features are more sharply accentuated than in the Eastern Shore streams. The reason for this seems to be the greater amount of elevation which this section underwent at the time of the post-Lafayette emergence whereby the streams were able to cut deeper valleys which now give high-banked estuaries with more marked terraces.

Stream Characters.

As soon as the "extended" streams of the Western Shore cross the western boundary of the Coastal Plain, *i. e.* the Fall Line, their valleys undergo a sudden change in character. From the narrow, steep-sided gorges which characterize the streams of the Piedmont,

the valleys change to open meadows bounded first by one or two broad terraces thirty or forty feet above the meandering channel and farther off by low, mild hill-slopes. These terraces can sometimes be traced up the streams westward from the Fall Line and are then found to merge into probably contemporaneous terraces, described later, which characterize a number of the Piedmont streams. Of the streams which present good illustrations of these confluent terraces may be particularly mentioned the *extended* Potomac, Anacostia river or the Eastern Branch and the Patuxent.

Proceeding down-stream from the vicinity of the Fall Line the stream banks become higher and slightly steeper, the flood-plains do not increase much in size, and the terraces appear to stand higher above the streams. At the same time the small side-streams trench somewhat into the terraces and their own upper courses cut deep narrow ravine-like valleys whose lower portions are somewhat leveled by an extension into them of a terrace plain. The characters of the down-stream terraces and side ravines are very well illustrated along the Patuxent to the east of Upper Marlboro' and near Princess Anne in Prince George's county. At these points, however, the river already begins to be influenced by the tides and thus comes almost within the estuarine zone.

Along this lower fluviatile portion the terraces stand generally in two series, as they do in the upper portions. The lower series has an average elevation of five feet above the present flood-plain, and its width varies from one hundred yards to half a mile. It is composed of fine gravels, quartz sands and a small amount of clay and loam. The upper series stands forty or fifty feet above the lower and is built of coarser gravels and cobbles. Near Princess Anne a gully in this upper terrace clearly shows that it is in part the result of cutting, in part formed by the deposition of gravels.

Both sets of terraces have been trenched by the small side-streams as they cut their way down to the present channel-grade of the main drainage. These streams pursue direct courses across the upper terrace, however, while their steep-sided trenches meander through the lower terrace in a manner which indicates that previous to cutting

of the present trenches they flowed for a time under flood-plain conditions. Such facts aid in picturing the conditions under which the streams have worked and give a clue to the relative variations in the rapidity of rise of the land after its Pleistocene depression, for these terraces represent stages in the fluviatile phase of Pleistocene deposition. The somewhat direct courses of the side-streams across the upper terrace indicate a rapid rise to some height which did not permit flood-plain conditions to arise. Having thus obtained an elevation of perhaps forty feet, the land remained quiet while the lower and broader terraces slowly formed. Finally, the land again rose, very slowly at first, so that the streams for a short time crossed extensive sand-flats just above the level of the water; then more rapidly, so that the runs trenched the meandering courses which they had been forced to assume during the short delay just preceding.

Drainage Plan.

On comparing the drainage patterns of the Eastern Shore and the Western Shore no fundamental differences are to be observed. The streams of the Western are generally shorter than those of the Eastern Shore and are of steeper slope, but the method of branching is the same and the streams belong to the same class, that is, they are autogenous. Indeed, these streams, though smaller, have, on account of their sharper cutting into the higher land of the Western Shore, developed even more typical autogenetic drainage than the low-lying and weaker streams of the east. Thus the branching of the headwaters of the Wicomico river in Charles county or of the Piscataway creek in Prince George's county present admirable examples of autogenous development. This type of drainage is also represented in Fig. 14.

Divides.

The most striking feature of the drainage of Southern Maryland is the location of the second-order stream divides. The Hypsometric Map of Maryland[1] expresses very well the unsymmetrical location of these divides, which always stand nearer the northern than the southern member of any two of the larger streams. Thus the streams of St.

[1] Md. Geol. Survey Reports, vol. i, plate vi, p. 142.

FIG. 14.—Unsymmetrical Divide between Potomac and Patuxent Drainage, near Leonardtown, St. Mary's County. (From Nomini Sheet, U. S. G. S.)

Mary's county, which flow southward into the Potomac are about three times as long as those which empty into the Patuxent. Similarly it is to be observed of the Calvert county streams that those flowing southwestward to the Patuxent predominate over those which drain eastward into the bay. This characteristic has already been recognized as a typical feature of the location of the divides of the eastern division of the subaërial Coastal Plain. It is a very interesting and remarkable coincidence that here in a region of more strongly marked relief and of more active streams is found a drainage system possessing the same unsymmetrically located divides which mark the sluggish drainage of the Eastern Shore. What makes the coincidence even more striking is the fact that the short steep streams lie to the east of the divides in both cases, while the longer, flatter streams are on the west slopes. These facts suggest very strongly that there may be some intimate and causal relation between the location of the divides on the Eastern and Western Shores.

If the divides and streams are studied on the small-scale Hypsometric map of Maryland a number of instances may be found which seem to suggest a simple explanation for the locations of the divides of Southern Maryland. In one case, that of Lyon's creek in Calvert county, the headwaters of the stream start with a southeastward course, but after flowing for two or three miles in this direction, make a sharp turn at right angles and flow off southwestward to the Patuxent. At the point where the creek makes the sharp bend a small stream heads and flows eastward into Herring Bay on the Chesapeake. Again in Charles county, southeast of Bryantown, the headwaters of a stream which empties into the Wicomico river start with a northeastward course, after a mile, sharply turn southeastward and again soon turn sharply southwestward. Near where this stream bends heads a small stream which joins the Patuxent just above Benedict, having taken a northeast course seemingly in direct continuation of the upper part of the preceding stream. These cases suggest that there has been some capturing by southeastward flowing streams and corresponding decapitation of westward and northeastward flowing streams. The large scale maps of the U. S. Geological Survey (see

FIG. 1.—TRIBUTARY OF THE CHOPTANK, NEAR QUEENSTOWN.

FIG. 2.—SEVERN RIVER, NEAR ROUND BAY.

Fig. 14) do not support this conclusion by detailed evidence. They do show, however, that the intricately branching headwaters of the southwestward flowing streams have pushed their weaker opponents very far to the northeast and have developed more intricate and extensive drainage systems than the latter.

Another factor which must be considered in any attempt to explain the unsymmetrical divides in Calvert county is the retreat of the cliffs along the western shore of the Bay. On comparing Plate VI, Fig. 2, with Plate VI, Fig. 1, there is seen to be a marked difference between the relief of the eastern and the western shores of Chesapeake Bay. The eastern shores are low and flat, while the western banks present picturesque cliffs such as those near Cove Point, shown in Plate II. This decided contrast is due chiefly to the fact that the Western Shore was originally elevated to a greater height than was the Eastern Shore. This initial difference, however, has been accentuated by more recent developments. The great storm winds on the Bay come from the northeast or the southeast, while the storms from the west are less severe and of shorter duration. Consequently the western shores are exposed to the severer storms and must withstand long-continued attacks of the larger storm waves. The result is that the bay shore of Calvert county, which from the configuration of the Bay is the coast exposed to the longest sweep of easterly winds, has been steadily undercut and worn back by the waves until the cliffs thus produced occupy a position several hundred yards west of the shore line which bounded the Bay in earlier times. The rate at which this recession has been going on is not known at present, but the members of the Coastal Plain Division of the Maryland Geological Survey have instituted a series of observations and measurements which in the future will yield some interesting results on this subject.

The fact of the recession of the cliffs is well established. In the course of the retreat the plane of the cliff face cuts across the topography of districts which formerly lay some distance back from the shore. The lower courses of many streams have been entirely removed, and their valleys which once descended to the bay level

in the usual fashion now appear as notches in the crest line of the cliff. These notches are very beautifully shown in the view represented by Plate II. Again, a shallow bench of clay is found to extend out under the water from the present foot of the cliffs to a distance of one-third or half of a mile beyond which the water rapidly deepens. This bench is undoubtedly the planed-off stump left by the waves as they cut their way landward, pushing the cliffs before them. The result of this westward migration of the Cove Point cliffs has been to shorten very materially the length of the streams flowing down the present eastern slope of the Calvert county divide, and the appearance is thus produced of an encroachment upon the headwaters of these curtailed streams by the longer streams of the western slope. The unsymmetrical location of the divide in Calvert county is, therefore, in part at least, only apparent. Even if shore recession were an adequate explanation for the lack of symmetry of the Calvert county streams the same would not apply to the streams lying between the Potomac and the Patuxent. In this case the shorter streams which flow into the Patuxent have not lost as much of their lower courses by wave erosion as have the Calvert county streams, yet the lack of symmetry is just as marked as in the latter case.

Estuaries.

As the streams come more and more under the influence of the tides their banks gradually recede and the waves are found to have destroyed considerable portions of the Columbia terraces. Thus passing to the estuarine portion proper, high, steep wave-cut cliffs replace the sloping banks, and sandy beaches or wave-fashioned contours appear in the stead of sandy terraces. The broader valleys which the streams of this subdivision carved out, produced broader estuaries than those of the Eastern Shore when the subsidence took place whereby the streams were drowned. Hence the shore features along the Potomac and the Patuxent are those of stronger waves and tides and the variety of forms is greater.

Besides spits and barrier-bars or beaches, such as have been described from the Eastern Shore streams, there have also been formed

along these shores V-bars, cusps, hooks, etc., which in many cases are worth studying because of the economic importance which they bear. For example, on the Potomac a lighthouse has been erected on the apex of the sawtooth-shaped V-bar which forms Piney Point. The sharper, shorter curve of the tooth is formed by the wide beach on the southeast or down-stream side, while the gentler back slope of the tooth consists of a long, gently curving, narrow beach which appears to be sometimes breached by the greater storm waves. The down-stream curve of the point, as well as the greater thickness of the down-stream beach, suggests that the growth of the point has been chiefly directed down-stream. For some miles above Piney Point there are long, smoothly curving beaches which bridge over the mouths of Flood and Herring creeks by means of low sandy bars, and thus give continuous and even sweeps of shore contours. These features are indicative of moderate and steady currents which sweep along the foot of the low cliffs and the barrier bars carrying sands southeastward to drop them off the point of the cusp. The shorter and more sharply-curving beach forming the southeast side of the point has been built by a weaker or less constant current which, flowing at right angles to the course of the first current, has carried the material brought by the latter around the point and down the short beach. These currents are the joint products of winds and tides, but the latter being regular and periodic in their action, are the controlling factors and have given the major characters to the estuarine shores.

Of a different type from the Piney Point bar is the formation of Point Lookout at the mouth of the Potomac. Piney Point was built by tidal currents which, for some reason perhaps resulting from initial inequalities in the shore line, set up eddies in whose triangle of confluence deadwater permitted bar-building. At Point Lookout the southerly drift along the bay shore set up by the prevailing northeast storm winds of the Chesapeake has built sand bars and beaches across Deep Creek into its neighbor, Tanner creek, and continued to grow southeastward until opposed by a current which sets along the curved beach and bar of Cornfield Harbor. This Cornfield Harbor current

has built bars and beaches across Point Lookout and Potter creeks, and the growth of these northwestward indicates that the current here runs in the same direction for the longer period, although it is possible that reversals in its direction sometimes occur. A very brief examination of the eastern beach of Point Lookout reveals the fact that its method of growth has been at times gradual and again more rapid. During most of the time the minor storms and waves bring sands along the shore to be deposited as a long, evenly-sloping beach such as is forming to-day. Sometimes, however, great storms have arisen and their strong winds have raised waves so large that they broke some distance out from the beach then existing. Thus a second beach was built up by the waves although several rods out from shore, and when the storm subsided the every-day waves increased the newly built beach. A record of these changes is left in the abandoned beaches and the marshy stretches between them which now lie within the present beach line.

Many examples of similar shore features can be found along the Patuxent and the Potomac. The Magothy and the Severn, in the sandy and clayey cliffs along their shores, also furnish favorable opportunities for such features; but the estuaries of the Patapsco, Gunpowder and Bush rivers generally have such low and marshy banks that there is no ready source for the sand necessary for the construction of beach topography.

Recent Stream Changes.

Mention has already been made in the appropriate place of the changes which have taken place in the streams and coast lines of the Eastern Shore during historic times. The same may be found on the Western Shore. When the country about Baltimore was first settled the many small creeks and the larger rivers offered, in their drowned lower courses, convenient harbors and landing places which were more or less accessible from the interior. At that time schooners of good size and moderate draft could lie alongside the wharf at Elkridge Landing loading with the iron obtained from the neighboring deposits in the Potomac group of formations. To-day the river is so choked with the sands, mud and gravels which wash down from the

Patapsco gorge and from neighboring hills, that large vessels can no longer sail so far up the river. Every year the floods and freshets bring down more waste from the land and add it to what has already been deposited, so that the channel grows steadily shallower and the landing grows less and less accessible.

The Anacostia river has had a similar history. Down to the early days of the city of Washington this stream was navigable for several miles from its mouth. To-day the channel and valley are so choked by the silt which the stream brings down that during high tide there is scarcely a foot of water on the broad flats which fill the streamway, and at low tide acres of marsh are laid bare. Thus within a hundred years this stream is seen to have effected great changes in its channel by deep accumulations of detritus derived from the surrounding hills.

One other instance of similar filling-in of a stream channel during historic times may be cited. Somewhere about 1785 Piscataway creek in Prince George's county was a navigable stream as far up as the town of Piscataway, which is now about two miles from tidewater of any depth. "At that date," says Alexander, "it certainly afforded a channel for vessels of good draft up to and a little beyond the Tobacco Warehouse." In 1835, however, the tortuous channel had so far filled up with mud and alluvium that the depth of water "at quarter ebb" was only 1 foot 10½ inches, and at high tide was only three feet. Moreover, at that time the processes of shoaling seem to have been active. J. H. Alexander says: "The progressive changes attributable to these causes [*i. e.* those causing deposition of sediment by checking the flow of the current], if they are to be judged from the effects of the last two years, are going on with considerable rapidity. Shoals of soft mud and shells, which were passed over at that period [1785 circ.], are now islands, covered with marine grasses and aquatic plants, and submerged only at high tide; and the public landing, once at the warehouse and afterwards nearly half a mile below it, is now difficult of access and appears to be fast receding down the river.[1] Since 1835 no record is found of further changes

[1] J. T. Ducatel and Alexander, J. H., Report on the New Map, etc, 1835, pp. 11 and 12.

in this region, but there is no apparent reason for doubting that the filling-in then in progress has continued to the present time.

These instances could be multiplied, but they leave no room for doubt that the strong tendency of all the smaller and most of the larger tidewater streams of Southern Maryland, as well as those of the Eastern Shore, is to fill up their channels with the detritus which they carry.

ECONOMIC PHYSIOGRAPHY OF THE COASTAL PLAIN.

Soils.

The various geological stages through which the Coastal Plain has passed have had considerable influence upon the soils, and through them upon the crops of the province. The early strata, those of Cretaceous and Eocene age, which are best developed in parallel belts along the northwestern boundary of the Coastal Plain, are sandy loams which yield good returns of fruit and garden truck. In this belt the most prosperous peach- and other fruit-farms have been located, and large quantities of fine peaches are still shipped from the northern counties of the Eastern Shore. The same belt extends northeastwards into Delaware and New Jersey where similar crops are raised. These strata carry with them a natural storehouse of valuable fertilizer in the form of greensand or glauconitic shell marl. In the early days of Eastern Shore farming this marl was much used as a fertilizer, particularly in Cecil, Kent and Queen Anne's counties.

In the central and southern counties the clayey loams which come from the Miocene or Chesapeake deposits afford extensive areas of good wheat, grass and tobacco lands, which formerly were of great importance to the state. Since the rapid development of the wheat fields of the West, however, the yield of these lands has grown comparatively insignificant, so that at present the farmers are not able to make wheat crops pay even by the aid of expensive fertilizers. Among the best-paying crops of the Coastal Plain are the products of the lighter sandy loams of the Pliocene (Lafayette) and Pleistocene deposits. These soils cover the whole Eastern Shore south of the Choptank and are also of importance on the more dissected Western Shore. Large and early crops of berries and melons are annually shipped

FIG. 1.—TOPOGRAPHY OF THE NORTHERN COASTAL PLAIN, IN CECIL COUNTY.

FIG. 2.—FARM-LANDS OF THE COASTAL PLAIN, IN TALBOT COUNTY.

from the cultivated areas of these soils, and the canning of tomatoes, corn and other products constitutes one of the important industries of the province.

Waterways.

The post-Lafayette and the post-Pleistocene submergences of the Coastal Plain have been of immense benefit to the inhabitants of Maryland. As a result of the drowning of the Chesapeake river ocean-going vessels are admitted as far inland as Georgetown, D. C., Baltimore, Havre-de-Grace and Chesapeake City. Valuable harbors also are provided, so that a large share of commerce has been attracted to Maryland shores. Besides interstate and international trade which is thus favored by the configuration of Chesapeake Bay with its deep exit to the high seas, trade within the state is greatly benefited by these waterways. That geologically recent submergence whereby the river valleys carved in post-Pleistocene times were drowned for more than half their length gave to the inhabitants of the Coastal Plain the most favorable facilities for easy and cheap transportation of their crops. The estuaries then formed are the entrances to tidal streams that penetrate into the very heart of the rich lands. They are generally of sufficient depth to admit the light-draught steamers plying on the waters of Chesapeake Bay and the numerous wharves which are encountered on ascending any one of the navigable creeks testify to the readiness with which the people have availed themselves of their natural opportunities. In the proper seasons these wharves may be seen piled high with the crates of fruit and other products which are being sent to Baltimore for distribution among the neighboring states.

Besides thus affording easy paths of intercourse with other important sections of the state the estuaries yield peculiar and characteristic products of their own. The same streams which, during the summer, are the arteries and highways of a commerce based on the products of the soil, become in winter the fields of one of Maryland's greatest industries—the oyster fisheries. Great quantities of these oysters are annually sent to Baltimore, and their gathering has given rise to a race of hardy fishermen and expert sailors only excelled by

the codfishers who sail every year to the Great Banks of Newfoundland. The oyster-canning industry, whereby the interior of the continent is supplied with canned oysters, has also arisen as an indirect result of the post-Pleistocene drowning. The diamond-backed terrapin, the duck and the other wild fowl of the littoral marshes also deserve a place among the list of resources which the geographic history of the province has bestowed upon this state.

Railroads.

While the many waterways which intersect the Coastal Plain have given boat traffic the best start among transportation facilities, railroads have been built to a number of points, thus connecting them more directly with the vigor and energy of the great commercial centers of Philadelphia and New York. Generally the railroad, seeking as it does that course which requires the least modifications from the natural topography in order to make an easy grade, has to pursue a more or less tortuous route. On the Eastern Shore the low and almost insignificant character of the divides and the shallow stream valleys permit the roads to run in very direct routes from one objective point to the next. A glance at the map of the state shows these routes and the indifference which they display towards the divides. It is also noteworthy that, although touching at several waterside towns, the railroads are confined on the whole to those wider portions of the small peninsulas where the hauling distance to the boat lines becomes something of a factor in the cost of transportation. By reaching these remoter points they are thus able to maintain a foothold in spite of the lower rates offered by the boat lines. On the peninsula of Southern Maryland the one railroad and its branch are compelled to hold pretty closely to the divide, as a short distance on either side the country becomes so cut up that it would be wholly impracticable to build a line. This is particularly true of the southeastern portion of the peninsula in Calvert and St. Mary's counties.

Effect of Topography upon the Inhabitants.

When the early settlers came to Maryland they found the tracts of the Coastal Plain occupied by peaceful tribes of Indians who lived

by fishing in the deeply indented rivers and hunting through the pine and hard wood forests which covered the interstream areas. The settlers themselves took to farming, encouraged by the rich soils, and also obtained plenty of fresh fish and oysters from the neighboring waters. Soon large and prosperous plantations grew up, which afforded by their products good incomes to their owners. The earlier inhabitants were thus mainly agriculturists. As the value of the oyster beds increased and the demands for the oyster grew the race of oystermen sprang up. These men naturally settled along the shores near their work. At present the two classes, which originally must have been somewhat mixed, can be clearly distinguished, the regular farmer keeping to the higher interfluviatile areas, while along the shores and in the vicinity of the large towns are the houses of the oystermen. On the Western Shore the dissection of the interior lands near the Bay has handicapped the farmer very decidedly, while the deep rivers and estuaries give good opportunity for the fishermen to ply their trade.

Thus the geological and physical features of the Coastal Plain, which are the direct results of its geological history, are seen to have almost wholly determined the pursuits and the habits of its settlers and inhabitants.

The Piedmont Plateau Province.

BOUNDARIES.

The Piedmont Plateau province is so called from its position along the eastern foot of the Appalachian ranges. It includes the broadly rolling upland of moderate elevation which extends from the eastern slope of the Blue Ridge and Catoctin mountain eastward to a line which runs approximately parallel to the coast, and marks the western limits of tidewater. This line extends from New York past Philadelphia, Baltimore, Washington, Richmond, Raleigh, and Augusta to Macon, Georgia, and along a comparatively narrow zone, is characterized by turbulent channels with waterfalls, cascades and rapids. To the west the streams may have long quiet stretches, while eastward all the streams open out into placid tidal estuaries. This

eastern boundary of the Piedmont Plateau is so noticeable a feature that it was early recognized and named the Fall Line from the manner in which it affects the streams. The Fall Line is really a zone several miles in width and probably marks a simple monoclinal flexure or a series of slight faults whose downthrows are towards the east. The western boundary of the province, formed by the eastern base of Catoctin mountain, is a clearly defined topographic feature, the cause of which will be later explained.

As would be expected when topographic boundaries are so well defined, the geologic and structural boundaries are almost equally distinct. On the east along a crenulate line which often coincides with the zone of falls or the Fall Line, lie the extreme western limits of the Coastal Plain sediments. These horizontally bedded and poorly consolidated deposits lie across the bevelled edges of the folded and crumpled crystalline rocks of the Piedmont Plateau, and present such a marked stratigraphic and lithologic contrast to them that the geologic boundary between the two provinces is sharply defined. The lack of completely consolidated layers in the Coastal Plain deposits has prevented the development of marked escarpments which, by their steep inland-facing front-slopes and long, gentle seaward-dipping back-slopes, would more clearly define the limits between the two provinces. On the west the transition from the highly altered crumpled schists of the eastern part of the province to the usually unaltered and less severely folded and faulted strata of the Appalachian region is not as sudden and well marked as the change from the Coastal Plain. From the crumpled gneiss of the eastern portion the Plateau extends across the highly plicated, but less profoundly metamorphosed, phyllites which form most of Parr's Ridge and its western slope. Farther west, along Catoctin mountain, in the uparching and great overthrust faultings of the limestone and quartzite upon the igneous rocks of the Blue Ridge, the structure approaches that of the Appalachians. Although the change in structure is thus gradual, yet the topographic change is more marked. The reason for this is that the great overthrust faults along the flanks of the mountains have elevated the hard quartzite which forms the crest; and sub-

sequent denudation has worn away the softer rocks on either side. A similar explanation applies to Sugar Loaf mountain, south of Frederick.

The Piedmont Plateau, as it has thus been bounded on the east and west, extends from Alabama to New York, and an homologous district can be traced farther northward, where it embraces Rhode Island, Connecticut, Eastern Massachusetts and the coastal portions of Maine and New Hampshire. Maryland, therefore, embraces only the small trapezoidal-shaped portion which is included by the Fall Line and Catoctin mountain, the Potomac and the southern boundary of Pennsylvania.

TOPOGRAPHIC ELEMENTS OF THE PROVINCE.

Viewed from any of the higher points of the Piedmont, such as the granite knoll just east of Cockeysville or, better, the divide between the Big and the Little Gunpowder Falls northeast of Glencoe, the topography resolves itself into three different classes of features. The first in importance is the broad rolling surface which extends in every direction as far as the eye can reach. Over this general surface are low knobs and ridges which seem to rise a little above the general level of the plateau. Finally, below the general level, numerous streams have sunk channels and valleys which at first escape notice, since all except the nearer valleys are masked by the rolling hills of the plateau upland. The following discussion is divided into three corresponding sections, namely, the Upland, the Valleys in the Upland, and the Residual Masses above the Upland.

The Upland.

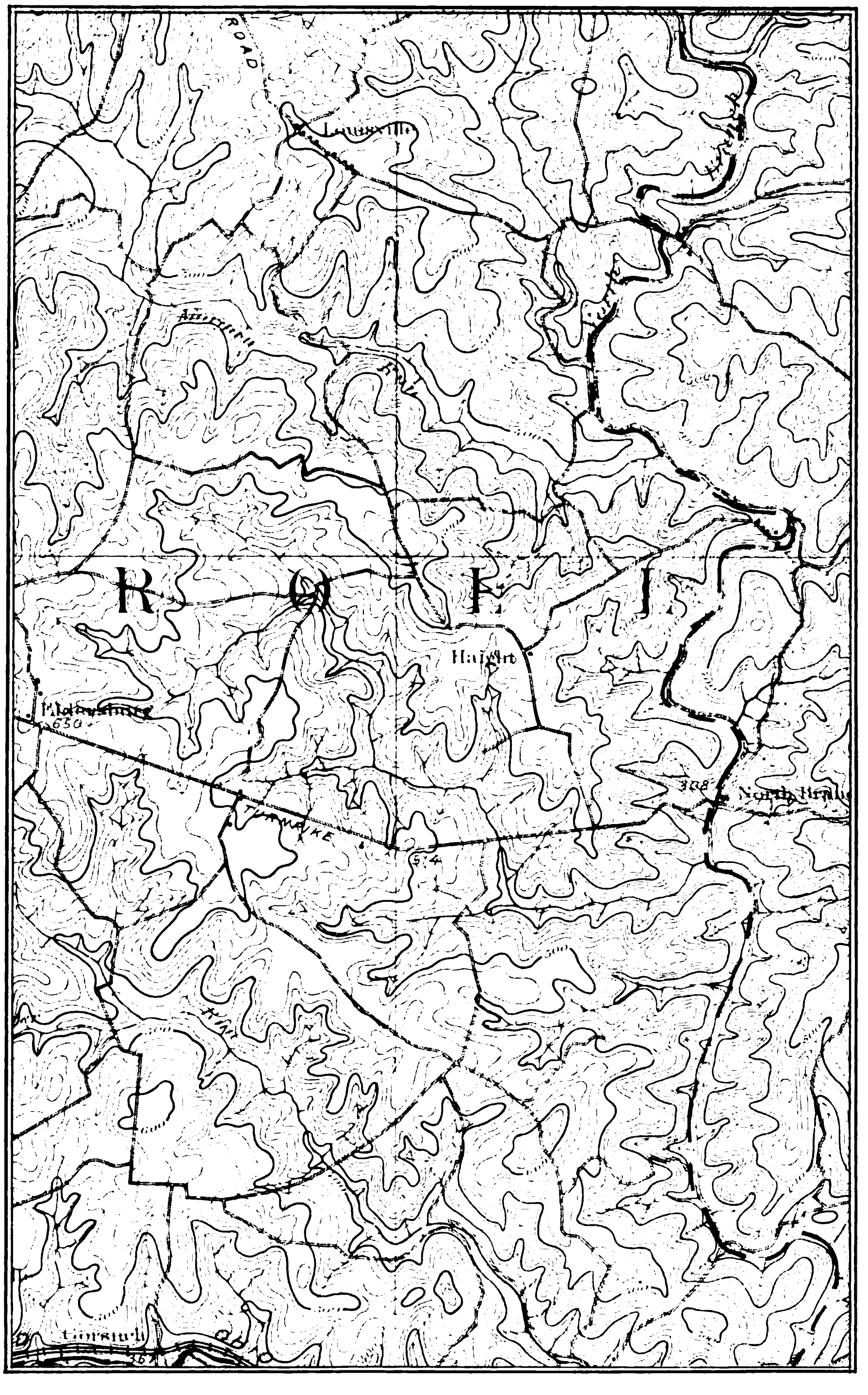
As has been remarked, the most striking feature in the topography of the Piedmont Plateau is the very even sky-line given by its many hills, whose rounded tops rise very nearly to the same plane. Could the valleys which have been cut out in the plateau be filled again, it is easy to see what the surface thus restored would look like.

Between the present streams, and at the points farthest from the channels, the divides have low, flat, convex curves, but as the present streams are approached the gentle arches of the divides change to

equally gentle concavities, which are sharply interrupted by gorges. The restored surface then would not be a perfectly even one, but would reveal a country of low, well-defined divides whose streams flowed through broad, open valleys bounded by gently sloping hills. This former surface, now a dissected upland, may be easily traced across Cecil, Harford, Baltimore, Howard and Montgomery counties, and through portions of Carroll and Frederick. Extensive areas of the earlier surface that have escaped dissection may sometimes be found where the land is drained only by very small streams at some distance from the larger and more active rivers. Such remnants are especially well preserved in the district along Parr's Ridge, on the two circumscribed patches of granite and gneiss, one of which lies north of Green Spring Valley and the other across the marble belt to the northwest of Towson, and on the upland between Big and Little Gunpowder Falls.

This old surface, which seems to approach very closely to the conception of a peneplain, is shown by the Hypsometric Map of Maryland not to be perfectly horizontal but to rise gently westward. Starting with an average elevation of about four hundred and fifty feet in the vicinity of the Fall Line, a steady rise of about twenty feet to the mile brings it to an average elevation of eight hundred and fifty or nine hundred feet along Parr's Ridge. This ridge forms the divide between the streams flowing eastward across the Piedmont Plateau into the Chesapeake Bay direct, and those which flow first westward to the Monocacy and thence through the Potomac to the Bay. Beyond Parr's Ridge the general surface of the Plateau at first descends somewhat rapidly, and then, after reaching the Triassic (Newark) deposits, very gently to the Monocacy. From the valley of this river the general surface ascends by stages to a bench along Catoctin mountain, on which Mt. St. Mary's College and Thurmont are located, at an elevation of about six hundred feet. The Upland may thus be considered as divided into two portions by Parr's Ridge, and each part will be found to have its own peculiar characters.

It appears, then, that the Piedmont region is much like a gently rolling plateau, whose surface, traversed from southwest to north-



MAP SHOWING PIEDMONT TOPOGRAPHY OF CARROLL COUNTY.

FROM ELLICOTT SHEET, U. S. G. S.

east by the dividing line of Parr's Ridge, slopes gently eastward and somewhat more sharply westward. This plateau surface differs from that of the most widely recognized types of plateaus, since it does not appear to be in any way dependent upon or the result of the structural features of the land-mass which it characterizes. In this respect it stands in strong contrast with the high plateaus of Arizona which owe their level, even surfaces to the horizontal position of the strata. Nor can it belong to the class of almost featureless plains, which appear where seas or lakes have left heavy deposits of sediments, as is the case of our own Coastal Plain. On the contrary, the highly inclined and folded crystalline rocks which compose the eastern portion of the plateau, as well as the more yielding faulted blocks of the Monocacy valley, are indifferently bevelled off, and the folds truncated by the surface of the upland.

The intricate foldings, as well as the great chemical and mineralogical changes which the rocks of the Piedmont Plateau have undergone, indicate that they once formed the deep-seated roots of more lofty mountain ranges. The sediments of the Appalachian Province also point to the same conclusion. In order to reach the surface of the land where they are now exposed to view, these rocks must have been subjected to long-continued and active erosion. The reduction of that lofty range could have been accomplished either slowly by the waves of the ocean, or more rapidly by the steady attacks of the elements. The probabilities are largely in favor of the second explanation.

As one traces the level of the Piedmont upland beyond the bounds of the province itself, several interesting facts are learned, which are important to one who would know the complete history of the Plateau. Within the Piedmont Province this general surface is found to cut across the tilted and now deeply dissected beds of the Newark formation; where these have been removed, the Silurian limestone beneath is seen to be below the general level of the upland. Tracing this surface farther westward the even crests of the Blue Ridge, North mountain, Warrior's Ridge, Dan's mountain, Savage mountain, and many others seem to properly form elements of this almost plane

surface. Northward and southward similar elements may be found such as the crests of Kittatinny and Schooley's mountains in New Jersey, and Massanutten mountain in Virginia. In fact, the Piedmont Plateau upland is generally regarded as being but the seaward remnant of a broad, gently rolling surface, which once extended westward beyond Alleghany Front, northward along the Appalachians into New York and New England and southward across the Cumberland Plateau of Tennessee to an unknown distance. This broad plain was cut indifferently across crystallines and folded sedimentary strata and was produced during the final stages of that long-continued denudation which has resulted in exposing the roots of the Piedmont mountain chain. Since the days of its formation, the surface of this old lowland has been elevated and much dissected by erosion, but there is every reason to believe that the high mountain crests are remnants of the once extensive peneplain. This peneplain was first described and studied in Pennsylvania and New Jersey, and was named by Professor William M. Davis of Harvard University the Schooley Peneplain,[1] after the mountain of that name whose crest line is one of the striking remnants of its surface.

The geological periods during which the peneplain was produced may be determined quite definitely by at least two lines of evidence. First its surface is found to bevel strata of all ages from the Archean to the Triassic. This fact fixes its maximum age; it cannot be older than the youngest rocks upon which it has been carved. The peneplain, therefore, must be younger than the Triassic or Newark beds which it traverses in the valley of the Monocacy, in the New Jersey area and in the broad valley of the Connecticut. In the second place any strata found deposited upon the peneplain must be younger than that surface, and vice versa the peneplain must be older than those deposits. Now it is possible to trace the general surface of the Schooley peneplain to the very edge of the continuous boundary of the oldest Coastal Plain sediments, and, outside this boundary, scattered outliers of those strata are found resting upon the uneven sur-

[1] Davis, W. M., "The Rivers of Northern New Jersey," Nat. Geog. Mag., 1890, vol. ii, pp. 81-110.

face of the plain. The geological map of Maryland shows very clearly how the Maryland portion of the peneplain passes beneath the Coastal Plain strata, and, indeed, everywhere along the boundary between the two provinces this relation may be clearly made out. The diagrammatic sketches forming Figs. 11 and 12 give some idea of the relations which the topographic features of the two provinces bear to each other. The new geologic map of Alabama also shows very clearly how the folded, faulted and planed-off paleozoic rocks of the southern Appalachians gradually pass beneath the nearly horizontal strata of the Gulf Series of the Coastal Plain. When Davis[1] recognized the significance of this burial of the peneplain surface beneath the Coastal Plain sediments it was believed that the Potomac group, the oldest and the lowest strata found there, was of Lower Cretaceous age. As these strata were found to be made up, in their lowest beds, of materials scarcely removed from their parent ledges, the surface of erosion on which they rested, *i. e.* the surface of the Schooley peneplain, was regarded as the topographic product of erosion during early Cretaceous times. The peneplain has been often called the Cretaceous Peneplain for this reason, and consequently the Piedmont upland was understood to have been produced during Cretaceous times. More extended stratigraphic work in the lower horizons of the Coastal Plain, together with careful studies of the vertebrate fauna and the flora of the Potomac Group, have finally led Clark, Marsh and others to refer the lower beds of this series to the Jurassic. A corresponding change must therefore be made concerning the age of the Schooley peneplain and of the Piedmont upland. Since on the one hand it must be younger than the Triassic beds across which it is cut, and on the other is at least as old as the late Jurassic formations which overlie it, the period of denudation during which it was produced would seem to embrace late Triassic and early Jurassic times.

Valleys in the Upland.

The valleys which have been incised in the plateau are characteristic of the province, but they are not all of the same type. One

[1] Davis, W. M., "The Geological Dates of Origin of certain Topographic Features, etc.," Geol. Soc. Am. Bull., ii, 1891, pp. 545-548.

set of valleys is distinguished by their steep sides and narrow channels, another class has broader valleys with milder bounding slopes and is not as extensive as the first class. Yet a third class has but one representative, namely, the Monocacy with its tributaries, which is distinguished by broad benches at several levels, wandering stream-courses with steep but low side slopes, and channels in which long stretches of smooth water alternate with zones of low rapids and rougher water.

All three classes of valleys are of considerable importance to the inhabitants of the province. By sinking their channels below the general surface of the plateau the streams have cut up or dissected that surface to such an extent that it has become rough and hilly, making the travelling *across* country quite arduous. This discomfort, however, the streams have themselves partly remedied by making their gorge-like valleys just the least bit wider than was needed for their own use, so that the early settlers found room for wagon-roads by the sides of the channels, and later comers have taken advantage of the same features in building their steel road-ways. Furthermore, the steep channels, full of little falls and cascades, which are confined by narrow gorges, offer many sites favorable for the building of mills and dams. A brief consideration of the characteristics and origin of these different types of streams and valleys will therefore be of interest.

The lower portion of the valley of Deer creek in Harford county has almost exactly the characters which distinguished the stream valleys of the old upland before it was dissected. The rounded hills slope gently towards the stream, and pass beneath a rather broad valley floor and flood-plain which accompany the stream for the greater part of its length. The channel itself has, along its lower portion, come slightly under the influence of recent uplifts, so that it is sometimes in a very shallow trench, but most of the time it wanders through the flood-plain unrestrained by walls. The general impression gained from a view of the valley is that of a gently rolling country with broad valleys and gently flowing streams, just such a landscape as is presented to the eye of one, who, standing on one of

the upland remnants, by the aid of the imagination restores the old surface of the country. In Cecil county two-thirds of the course of each stream generally flows in such a valley, while the lower third occupies a more rugged channel.

Those streams which empty into Chesapeake Bay, however, south of the Little Gunpowder do not present such characters except in the immediate vicinity of their headwaters. Such streams as the Little Gunpowder, the Big Gunpowder, the Patapsco and the Patuxent, for the greater portions of their courses flow through narrow gorges of gradually increasing depth and width. Although the map shows that the courses of the streams are often somewhat winding, the topographic map, or better still an examination of the streams themselves, reveals the fact that this indirectness in course is not the result of wanderings over modern flood-plains, but that the gorges themselves follow more or less closely the swings and turns of the channel. Along the largest streams, such as the Big Gunpowder and the Patapsco, there is barely room to admit the railroad tracks and an occasional wagon-road. Among the streams belonging to this class the channel course is not affected to an important degree by the different rocks through which it cuts and in this respect differs from certain other streams to be noticed below.

These streams are also characterized by channels whose varying grades reveal how recent an event, relatively speaking, was the elevation which caused the streams to thus entrench themselves below the plateau. Beginning at the mouth of any one of these streams, as the channel is followed up-stream, its grade is found to be very steep for several miles. The distance to which this steep grade extends depends upon the size of the stream and to some extent upon the character of the rocks flooring the channel. Plate XIX shows that the Big Gunpowder has this steepened grade as far as Loch Raven, or for a distance of something over eighteen miles up-stream from its mouth. Above this point the Gunpowder runs in a limestone valley for eight miles until reaching Warren Mills, beyond which the channel is continuously on gneiss, phyllite or serpentine to its source in Pennsylvania. The easily reducible marble above Loch

Raven has not maintained the steeper abnormal, convex grade maintained below that point, and when the gneiss is again reached the grade has changed to the normal concave character.

Gwynn's Falls and Jones' Falls (Plate XIX), streams of about equal size, have both pushed their steep grades about eight miles up-stream, reaching Powhatan and the Lake Roland dam respectively. These are smaller streams than the Gunpowder, and therefore have not had the volume and the power needed to reduce their grades to as low a slope, or to push the steep grades back as far as the latter stream has done. The zone of falls, approximately eight miles wide, which is here described, marks the position of the zone of displacement, which has been denominated the "Fall Line." All these streams with their gorges and troubled rock-ribbed channels show that they have not yet succeeded in reducing their courses to even and matured grades. These immature characters do not generally extend, however, quite up to the heads of the streams. For several miles from their sources streams like the Gunpowder, Gwynn's Falls and the Patapsco have the broader, open valleys and quiet currents which characterize mature drainage and, like the lower course of Deer Creek, reproduce the old upland surface.

Certain tributaries of the streams above referred to occupy valleys which depart from the normal type of side-valleys of youthful streams. Instead of being confined between the steep walls of narrow, ravine-like gorges, as is usual for the tributaries of large streams in areas recently elevated, these favored brooks flow through relatively broad valleys with fertile floors, but steep sides. Western Run and a small tributary of Beaver Dam creek, Dulaney's creek and Mine Bank run are a few of the streams belonging to this class. Jones' Falls is an independent stream which also belongs in this class. Most of these broad valleys have been opened out on areas of soluble marble, leaving the surrounding gneiss and granite areas standing prominently above the lowlands. In the case of the headwaters of Little Deer creek, however, a broad lowland bordering the stream has been opened out on the band of yielding and crumbling phyllites, which runs northeast and southwest across Harford and Baltimore

counties. The same is true where some of the tributaries of Western Run cross the phyllite, although in the latter case the stream is flowing not parallel with but across the strike of the foliation. Besides their breadth and their arrangement parallel to the general direction of the structure of the country, these broader valleys are in some cases also distinguished by containing remnants of the earliest strata of the Coastal Plain series. These remnants are of two horizons. One consists of the variegated clays and washed gravels, which form a portion of the Potomac Formation, and it is found chiefly as small patches in the Green Spring Valley, in the vicinity of Lutherville and about Oregon. The other horizon is that of the Pleistocene, whose deposits consist of gravels and sand brought in by the larger streams. These deposits are much more extensive than are those of the Potomac, remnants being widespread over the valleys about Cockeysville, Dulaney's Valley, Green Spring, Mine Bank run, and the valley of Western Run. The Pleistocene may also be traced along the narrow gorges of several of the streams which, for portions of their courses, flow through the open valleys.

The presence of remnants of the Potomac and Pleistocene formations in these valleys gives some clue to the geological period during which they were etched out. Since they were sunk below the general level of the upland they must have been one of the sets of valleys carved out by streams acting under the revivifying influences of an elevation just succeeding the period in which the upland was formed. In the preceding section it has been shown that the upland surface, whether a peneplain or a surface of advanced maturity, was produced in the interval between the elevation of the Newark and the early portion of Potomac time. These valleys are, therefore, younger than earliest Potomac time. At the same time, since they contain Potomac deposits, they cannot be younger than late Potomac time. As these deposits are of later Potomac (Patapsco) age the valleys containing them must be of middle Potomac date. Recent studies in the Potomac group have led to its being referred in part to the Jurassic and in part to the Cretaceous, and from the data given above the date of formation of these valleys is probably very late Jurassic or early Cretaceous.

In the western half of the Piedmont Plateau, within the drainage of the Monocacy river, small level-floored valleys, eaten out along limestone lenses, are also frequently met with. The limestone of these valleys is regarded by many as identical with the Cambro-Silurian limestone of the Great Valley and of Frederick, but a study of the stratigraphic relations in the Monocacy valley makes it appear very probable that these lenses were completely buried by the estuarine deposits of the Newark (Triassic) formation. No remnants of this formation were found within these limestone valleys so that it cannot be definitely asserted that they are of pre-Newark age. On the other hand the fact that they are invariably occupied by small streams, which have there developed subsequent courses, rather indicates that these valleys have been developed during more recent times than have their counterparts in the east.

West of Parr's Ridge the upland declines rather gradually while on the phyllites and disappears entirely when the eastern boundary of the Newark formation is passed. On these yielding rocks a terraced and dissected lowland has been carved out. Its highest level is an extensive but dissected plain maintaining an almost uniform height of five hundred feet above tide from the Potomac along Catoctin mountain to Emmitsburg. This elevation increases slightly northward in Pennsylvania, but is remarkably constant through Maryland and Virginia. Although it was formerly a continuous lowland extending across the valley of the Monocacy, subsequent elevations have caused large portions of the surface to be removed by erosion. The extent of the remnants is variable; large areas may still be seen about Frederick and to the south, but northward towards Emmitsburg the surface is represented by areas only a mile or two in width.

Below this higher level the Monocacy has at different periods in the past cut lower and less extensive valley floors or valley lowlands, which now appear as broad benches of varying width, overlooking the present stream channel. At a level of four hundred and fifty feet or fifty feet below the uppermost surface is the first of these subsequent terraces. This is the most persistent and uniform of the lower terraces and often attains a width of three to five miles. It is best seen over the district between Thurmont and Emmitsburg.

Following the present channel of the Monocacy, and sometimes traceable for short distances up the larger side-streams, is a third terrace, the lowest of the old valley floors. It has an elevation of about three hundred and fifty feet in the vicinity of Frederick and southward, rising very gradually northward where it is more widely dissected and removed. The width is variable, but rarely exceeds a mile. A steep slope leads down from the second terrace. Below this lowest bench the present channels have entrenched themselves to a depth of one hundred feet or less.

The channel of the Monocacy, though of gentle slope and graded for considerable stretches, is often interrupted by low unreduced ledges. It generally lies five or six feet below an extensive flood-plain which is submerged for more or less protracted periods, several times a year. Side-streams joining the Monocacy have trenched the flood-plain during its unflooded periods, and have along their lower courses developed smaller flood-plains of their own. The channels of these tributaries are not as perfectly graded as is that of the main stream, and frequent low falls interrupt them.

The lowlands eroded on the yielding rocks of the Newark formation are one of the striking features of the Piedmont Plateau throughout its extent from Massachusetts to Virginia. The lowland of the valley of the Connecticut river is the most extensive and best known of these valleys. As the Plateau has there suffered greater elevation the valley is cut to a greater depth below it than in the case of the Monocacy, and is therefore a more pronounced depression in the general topography of the upland. The valley of the Connecticut, however, was within the limits of the area covered by the great Ice Sheet of the last Glacial Epoch, and as a result of modifications imposed upon it by the ice and the glacial rivers its minor topography is different from that of the corresponding valley in Maryland which did not come under these influences.

There are then, as has been shown, three types of valleys sunk below the Piedmont upland: the narrow circuitous gorges with steep sides and rapid currents and closely fitted by the streams which made them; the broader, level-floored valleys developed along yielding lime-

stone or phyllite and occupied by slightly meandering streams which may later on enter narrow gorges, and the broad even-topped, terraced lowland of the Monocacy and its tributaries.

Residual Masses above the Upland.

As the general surface of the Piedmont Plateau is traced northward into New England it is found that there are several prominent elevations which rise sharply above the general level of the plateau. Mount Monadnock, Mount Ascutney, and Mount Wachusett are prominent examples of these features. Going southward into the Carolinas similar prominences may be observed, but more striking than these is the manner in which the surface may be traced in and out among the high peaks of the Black mountains, particularly in the vicinity of Asheville. These various mountains and peaks are evidently portions of the old land area which for some reason was not reduced during the period of base-leveling that produced the even surface of the upland. They may owe their present prominence to one of two causes, either they are composed of rocks of superior resistance to those surrounding them or they were situated so far from the seacoast that sufficient time did not offer in which the streams could work back to and reduce them. Mount Monadnock was first described as being such a remnant, and its name has been adopted as a designation for all more or less isolated residual masses left standing above the general level of the peneplain.

Maryland presents only a few low examples of such *monadnocks* above the general upland of the Piedmont. Rocky Ridge and its fellow, Slate Ridge, both in Harford county, are the best-marked illustrations of this class of topographic forms. Both ridges have but a slight elevation, not more than one hundred feet above the plateau surface, and owe their prominence to the fact that they are composed of unusually resistant rocks. Rocky Ridge marks a band of quartzite and conglomerate, and Slate Ridge, as its name implies, is the outcrop of a band of roofing slates which is pinched into the phyllite. Plate I shows something of the character of the crest of Rocky Ridge, and a general view of the west side of Rocky Ridge is given in Plate XVII. The same quartzite which forms Rocky Ridge occurs along the south side of Green Spring Valley and forms Set-

ters Ridge at the west end of that depression, but this ridge is less marked in elevation and not easily distinguished from the other inequalities of the general surface. In the valley of the Monocacy, and rising above its floor to an elevation of twelve hundred feet, stands Sugar Loaf mountain, clearly a monadnock with respect to the broad, even five hundred foot level of the valley. The mountain is also a monadnock with respect to the Piedmont upland which, crossing Parr's Ridge at eight hundred and fifty or nine hundred feet, was found to decline to six hundred feet along the base of Catoctin mountain at Mount St. Mary's College, Emmitsburg.

Summary.

The general topographic features of the Maryland Piedmont Plateau have been found to be similar to those of the same topographic province along other portions of the Atlantic Slope. The most important topographic feature is the rolling surface which forms the upland of the Plateau. This surface was brought to its former slight relief by the action of rivers and streams, and was bevelled down across hard and soft rock indifferently. It has a general gentle rise westward from an elevation of four hundred feet at the Fall Line to a maximum of nine hundred feet at Parr's Ridge, whence farther west it declines to an average elevation of six hundred feet along the base of Catoctin mountain. Above this general level rise low residual masses or unreduced monadnocks, such as Sugar Loaf Mountain and Slate Ridge, while below the upland narrow gorges have been cut out, limestone lowlands have been etched, and on the Newark formation broad, terraced valleys have been carved.

THE ROCKS AND THE STRUCTURE OF THE PIEDMONT.

In order to understand the systematic development of the Piedmont drainage, the various rocks, their relative resistances and their arrangement with reference to each other must be considered.

The Rock Types.

The rocks of the Piedmont province may be conveniently considered in two divisions, an eastern and a western one, as was the topography.

The eastern portion of the Piedmont, eastward from a line joining Seneca on the Potomac and Manchester, Carroll county, is largely composed of rocks which are now completely crystalline and show little evidence of ever having been deposited as sediments. Only a few scattered areas of the eastern division are composed of semi-crystalline rocks which have been altered from former sediments to their present state by the action of great, long-continued heat and pressure.

The crystalline rocks are probably older than the semi-crystalline metamorphosed rocks, possibly representing the lower members of the Paleozoic series to the west, and are generally referred to the Archaean or the oldest of the geological eras. They include granites, diorites, peridotites, pyroxenites, gabbros, marbles, quartz schists, and gneisses. For the present purposes these rocks need not be specially discussed. The granites and the closely related diorites differ slightly in color and in the characters of their dark-colored constituents. They are both quarried extensively. Both yield to erosion at about the same rate. The darker, heavier rocks, called gabbro, cover an area about equal to that of the granites and diorites but are concentrated about Baltimore, Havre-de-Grace and Rising Sun and in a belt through central Harford county. On weathering the gabbro usually yields a characteristic heavy reddish soil due to the large percentage of original ferro-magnesian constituents. On the accompanying map (Plate XVI), the gabbro, granite and diorite have all been given the same symbol with the gneiss which covers the larger portion of the eastern Piedmont slope. The latter is a normal gneiss of a white, a dark gray, or blue color, which has been very completely metamorphosed by repeated squeezings. It has a complicated structure, shown by its large and fine crumplings and plications, and is composed of bands of varying width which often show marked differences in resistance to erosion.

The marbles are completely crystallized saccharoidal masses which often show dolomitic bands with impurities in the shape of irregular zones of accessory minerals, such as brown mica, white hornblende, tourmaline, etc., resulting from a recrystallization of the original

FIG. 1.—PIEDMONT PLATEAU, LOOKING WEST FROM SLATE RIDGE.

FIG. 2.—HERRING RUN, BALTIMORE COUNTY.

impurities. Bands of quartz schist, composed chiefly of secondary quartz and divided into numerous planes by layers of flaky mica often accompany the marbles from which they are sharply defined, while they change gradually into the gneisses which may be present on the other side. The quartz schist is closely allied mineralogically to the metamorphosed sandstone and conglomerate now appearing as the Cambrian quartzite of Rocky Ridge in Harford county. Next in importance to the quartzites and schists are the peridotites and pyroxenites. These are dark, medium fine-grained rocks of considerable specific gravity which occur, not over large areas, but in restricted patches. One long, narrow, irregular band is located in northern Harford county running northeast and southwest, another is about fifteen miles long and runs northeast-southwest midway between Sykesville and Woodstock. Just north of this band is a large circular area at Soldier's Delight and an irregular one lies between the latter point and Catonsville. Both varieties of these basic rocks are subject to a constructive alteration or chemical change which produces serpentine or steatite according as the original rock was peridotite or pyroxenite. The Bare Hills is composed of a small patch of the altered rock serpentine.

A narrow interrupted diabase dike extends from a point west of Guilford, northward and eastward through Worthington Valley past Parkton, and so through the northwest course of Harford county out of the state. This rock weathers very easily into a red soil, leaving irregular fragments scattered over the surface or in the loam. Since in this portion of the state it does not show any characteristic topographic form it has been colored like the gabbros with which it is closely related.

The evidently clastic rocks of the eastern Piedmont are the quartzite already mentioned in connection with the quartz schist and detached areas of the same phyllites which chiefly underlie the western division. Beginning in a small point north of Reisterstown, the phyllites extend northward, then turn northeastward, gradually widening near Parkton and pass out into Pennsylvania. These rocks are finely laminated sericite and chlorite schists, which are much

contorted and finely puckered in the eastern division. They yield very readily to erosion. In their midst about Cardiff they have pinched in a deep lens of fine-grained blue-black roofing slate, on either side of which is a band of the quartzite conglomerate. The slates, the quartzite and the conglomerate, and the phyllite are distinguished by separate symbols on the map.

On the west the rocks of the Piedmont Province are semi-crystalline, crystalline and clastic in nature. The semi-crystalline rocks are the phyllites and their associated crystalline fine-grained limestones. The phyllites, which are much faulted and puckered, often hard to separate from the gneiss of the eastern division along the eastern slope of Parr's Ridge, become less and less disturbed westward. The crystalline limestones, or fine-grained marbles, occur particularly in the vicinity of Westminster and Union Bridge. The eruptive rocks of a basic character found in the phyllites have been so highly altered by pressure that they now appear as chloritic and epidotic schists. These once wholly crystalline rocks are probably of Archaean age; but other basic eruptives in the form of diabase dikes and sheets were pushed up through the Newark strata during Mesozoic time. These dikes are but little altered, but the baking to which they subjected the adjacent sandstones and shales has hardened the latter and changed the prevalent red color to a bluish-black or a deep brown.

Among the remaining sedimentary rocks in the western portion of the Piedmont are the soft red shales and sandstones of the Newark, the Shenandoah limestones of the Frederick valley and the Cambrian quartzites.

Topographic Valences of the Rocks.

The various rocks enumerated above, by reason of the different degrees of resistance which they offer to weathering and erosion, control in great measure the topographic features of the province. Although the facts at hand are insufficient for a detailed discussion of the topographic characteristics of each rock type, they may be discussed under the following heads:

The *gneiss*, *granites* and *gabbro* all offer about the same resistance.

They form by far the greater portion of the general surface of the plateau, and are characterized by rounded hills and gentle slopes on the old upland surface. The steep walls of the recent gorges and the slopes of the hills leading down to the broad valleys are also characteristic of these rocks. With them have been grouped the diorite and the diabase because of their small areal extent and essentially similar topography. There are bands of varying resistance distributed throughout the rocks of this group, particularly the gneiss, which is by nature of variable lithologic character. These zones are, however, so irregular in size and position that for the present one cannot say more than that they follow the general direction of the gneiss foliation. They are expressed in the topography by occasional expansions or contractions in the gorge-floors and by softening or intensification of the steep contours of the valley walls.

Next in areal importance come the *phyllites* of the western and the northern central portion of the Piedmont. In the tongue-shaped area of the latter section the phyllites produce more rounded hills and gentler slopes than are general on the gneiss. Where streams cross the band, as Black Rock run does, for example, the valleys are much broader and have milder channel slopes than those which characterize the same streams in the gneiss. Deer Creek has developed a fair-sized subsequent tributary on the phyllites, and other streams crossing it sometimes send out little feeders along the strike of the formation. The large area of phyllites forming Parr's Ridge and part of the western slope present very similar topography but on a more extensive scale. The small headstreams of the Monocacy drainage carve deep narrow valleys, but they have more rounded slopes and wider floodplains near their headwaters than do corresponding small streams on the eastern slope. The prominence of Parr's Ridge itself is due to its location at the headwaters of the two opposing drainage systems and not to any marked resistance of the phyllitic rocks forming it.

Folded in with the phyllites of the western division are lenses of *limestone* and *marble,* whose high degree of solubility has permitted the hollowing out of broad flat-bottomed valleys. These valleys find

their counterparts on the eastern slope of the plateau in long narrow valleys which have been opened out on curving bands of marble. Green Spring valley, Worthington's valley and the related meadow-lands along Western run are typical illustrations. Long Green valley on the Baltimore and Lehigh Railroad is more nearly like the level-bottomed, lens-shaped valleys of the western portion. About Lutherville several smaller areas of marble coalesce and form a broad, open lowland, now slightly dissected. Not all the marble bands of the eastern division, however, have been etched so completely. The two parallel bands of marble lying southwest of Ellicott City are crossed by headwater streams of the Little Patuxent, which are now just beginning to work out valleys little lower than the general upland level. These limestone and marble bands are the weakest topographic factors in the Piedmont complex.

Next to the limestones and marbles in weakness come the various members of the *Newark formation.* These shales, sandstones and limestones form the benches and terraces along the Monocacy river and are wearing away only less rapidly than the limestones and marbles. Where surfaces of erosion are preserved in this formation, as on the benches and terraces, the topography is almost featureless. The slopes from one level to a lower one are usually seamed by small ravines of slight depth and moderate inclination. When streams have cut down to the present level of the Monocacy they have comparatively broad bottomlands along their lower courses and have already advanced beyond Infancy even for some distance up-stream. All these characters obtain in spite of the comparatively recent periods of uplift which the Triassic district has undergone. The diabase dikes which cut the other rocks of the Piedmont and are in the western portion at least of Triassic age, weather so readily that they are of no topographic value when they occur in the gneiss and limestones of the eastern portion. Where they have baked the Triassic shales and sandstones west of Parr's Ridge, however, their presence is revealed by low swells upon the otherwise gently undulating plain. When a stream crosses the diabase dikes the valley slopes of the stream are steepened and numerous fragments occur in the slightly roughened channel.

The most resistant rocks, those forming the most prominent topographic features, are the serpentines, the slates, the quartz schists and the quartzites. The most extensive of these rocks are the serpentines and steatites which, as has been mentioned, are alteration products from peridotites and pyroxenites. As these rocks are the results of changes near the surface they offer much fewer opportunities for chemical and physico-chemical processes of disintegration than do rocks of a different nature. They therefore now stand out as low ridges or rounded knolls above the surrounding gneiss. The serpentine is most striking topographically where it is crossed by streams, for then its resistance to weathering and to the wear of running water cause it to form steep, boulder-strewn, rocky gorges with steep, rough channels. The best illustrations of these characters are found where the North Branch of the Patapsco crosses a broad band of serpentine several miles north of Marriottsville; where Winter's run crosses the same band, and farther north, in Harford county, where a tributary to Deer creek crosses a band of similar rocks. The rounded but barren slopes of the Bare Hills, and the elevated, irregular interstream area of Soldiers' Delight, rising to one hundred feet or more above the surrounding surface, are each caused by the presence of large masses of this rock.

The serpentines are only slightly less prominent than the *slates*, the *quartzites* and the *schists*. These three types form the most prominent eminences above the upland. The quartz schist, or Setters Ridge quartzite, as it is sometimes called, forms a distinct ridge overlooking the marble-floored Green Spring and Mine Bank run valleys. In Harford county the prominent elevation of Rocky Ridge is maintained by a heavy band of quartzite and metamorphosed quartz conglomerate whose unyielding qualities are also responsible for the rock towers and turbulent channel where Deer creek crosses the ridge at "The Rocks." A near view of the water gap and the ridge is shown in Plate I. Slate Ridge is a somewhat broader and less marked ridge situated north of "The Rocks," and is caused by the presence of the band of slates between Cambria, Md., and Peachbottom, Pa. Although the slates of Slate Ridge are probably stratigraphically re-

lated to the quartzites of Rocky Ridge, they have been separately colored on the map because of their lithological difference, while for a like reason the Setters Ridge quartzite which is probably a product of fumarole action[1] has been classed with the Rocky Ridge quartzites because of their lithologic similarity.

In conclusion, it may be said that the Piedmont Plateau rocks present different types whose topographic expressions are sufficiently dissimilar to permit of the divisions which have been discussed. These divisions have been represented on the map forming Plate XVI, and the symbols have been arranged, not in a chronological, but in a topographical order. Those rocks which are the most resistant and form the most prominent features stand first at the head of the column. They are succeeded by weaker and weaker rocks until the soluble limestones and the incoherent Coastal Plain deposits are reached.

Structure of the Piedmont.

Whatever may have been the original structure and the stratigraphical relations between the various semi-crystalline and crystalline rocks of the Piedmont Plateau, all traces of these features have been destroyed by the profound dynamical metamorphism to which they have been subjected since their formation. This metamorphism has induced in the rocks a secondary foliation by arranging the mineral constituents in long parallel lines and planes, but this foliation bears no close relation to the possible original bedding planes of the rocks. A cross-section of the plateau shows that the foliation planes dip steeply east and west down towards an axial line which crossing the Potomac near Great Falls proceeds northward past Gaithersburg and Westminster into Pennsylvania.[2] On the western side of the axis of this fan-like structure the strike of the foliation of the phyllites with their infolded lenses of marble is parallel to the axis. On the east the gneiss, with its infolded phyllites and marbles, keep a northeastward course to the latitude of Westminster, then make a sudden turn to the eastward and, following this new direction

[1] See Md. Geol. Survey, vol. i, 1897, p. 163.

[2] Thus it appears that the structural axis is not related to the boundary between crystalline gneiss and semi-crystalline phyllites.

for some miles, the bands of marble, quartz schist and gneiss again turn northeastward. The arrangement of the marble in long parallel bands which make a sudden eastward curve with most of the Paleozoic strata of Pennsylvania is suggestive of an original Appalachian structure. No reliance, however, may be put upon these appearances as indicating the original relations to the gneiss.

The western half of the fan shows a decreasing amount of deformation, although the blue and white Paleozoic limestone about Frederick shows a very considerable crumpling of its bedding planes. Upon the eroded surface of the phyllites and the blue limestone rest the beds of the Triassic sandstones and their intercalated diabase dikes and sheets. The latter are deeply and thoroughly broken up into angular blocks by a great number of fault planes produced prior to the formation of the upland. Many of the fault blocks have been greatly changed from their originally horizontal attitudes, while some may still retain their early positions.

RELATIONS OF STREAMS TO STRUCTURE.

The structure of the Piedmont Plateau is so different from that of most portions of the earth's surface that the problems connected with the relations between it and the drainage lines found thereon are much simplified. Although the true structure of the Piedmont is probably very much more complex than that of the Appalachian province, the land surface has undergone so many partial or complete repetitions of the topographic cycle that all the influences which original foldings and faultings may have exerted are now unimportant. For this reason it is impracticable, in the study of the Piedmont drainage, to apply the more detailed refinements which Davis, Hayes, Campbell[1] and others have used so successfully in studying the Appalachian streams.

Present Discordant Locations of Streams.

Any map giving the drainage of the state will show that the streams flowing down the eastern slope of Parr's Ridge to the

[1] Davis, W. M., "The Rivers and Valleys of Pennsylvania," Nat'l Geog. Mag. i, 1889, p. 183. Hayes and Campbell, "Geomorphology of the Southern Appalachians," Nat'l Geog. Mag. vi, 1894, p. 63.

Chesapeake follow approximately parallel courses which have a general southeastward trend.

The general trend of the stream courses is almost exactly at right angles to the slightly eastward curving, southwest-northeast strike of the foliated crystalline rocks which make up the complex series of the Piedmont. As pointed out above, these crystallines embrace numerous bands of resistant rocks alternating with zones of more yielding character. Although resembling the Appalachian mountain district in this respect, even the main stream courses of the Piedmont do not pass from one yielding band to the next as they do in the Appalachians, see Fig. 9, but appear quite indifferent to such variations. For example, the Big Gunpowder pursues a course wholly independent of the numerous broad marble bands which it crosses, while its tributaries—West Branch, Western Run and Piney Run—also traverse indifferently gneiss, phyllite or limestone. The headwaters of the Patuxent south of Marriottsville, the streams of Worthington's valley and Gwynn's Falls near Pikesville are further instances of the lack of co-ordination between the Piedmont rocks and the streams flowing across them. Evidently the streams of the eastern portion of the Piedmont have not long been located in the rocks now exposed or else the law of divides on hard rocks, valleys on soft or yielding ones here finds many exceptions to the rule.

Among the streams of the western section of the Piedmont occur many similar cases of unadjusted or discordant streams. The small portion of the western section shown on the map, Plate XVI, reveals several such cases even among the smaller streams where adjustments are usually most marked. The larger geological map of the state shows a number of westward flowing streams whose courses appear to be quite unaffected by the presence of limestone lenses. The Monocacy itself pursues a course which is at present rather independent of the rocks it crosses. From Emmitsburg southward for thirty miles the main stream and its tributaries flow back and forth across soft shales or sandstones and several times cross the harder diabase dikes. When opposite Lewistown the stream leaves the Newark formation and for twenty miles follows the great band of Shen-

andoah limestone forming Frederick valley. Not content with this selection the Monocacy again changes, this time from limestone to phyllite, and after meandering back and forth across limestone and phyllite, finally cuts across a corner of the Seneca creek Triassic sandstone to join the Potomac. So imperfectly adjusted a course as this could hardly have been developed upon the rocks of the Monocacy valley as now exposed. The long lenticular area of limestone would surely have exerted control enough to confine the growing stream within in its boundaries.

To sum up it is clear that, as a whole, the streams of the Piedmont Plateau follow courses which have not been strongly influenced by the arrangement of the rocks now exposed to view. Many cases of marked discordance can be found not only among the larger, more powerful streams, but also among the smaller, younger streams where adjustments are most common.

Normal Arrangement is Accordant.

If one attempts to construct in imagination the general drainage plan of the Piedmont, as it would appear after having developed through a normal topographic cycle, the present unadjusted drainage stands out quite sharply through contrast. Following on Plate III the general trend of the structure, and supposing that both the Susquehanna and the Potomac through their size were able to maintain their present courses, the general features of the smaller drainage lines may be outlined as follows. The side streams starting from the Potomac and the Susquehanna would be working along the strike of the gneiss, phyllite, limestone, etc., and thus be able to cut out their valleys easily and rapidly. The north and south drainage would thus have distinct advantages over the streams flowing eastward to the ocean, as the latter streams would have to cross the resistant as well as the yielding strata. While one of these eastward flowing streams was attempting to reduce the harder bands a stream working its headwaters from the north or from the south along one of the yielding bands would easily be able to intercept the less favored stream and carry its headwaters off along a course parallel with the strike. The least resistant bands, such as the phyllite extending

southwest from the Susquehanna or the limestones running northward from near Point of Rocks, would determine the location of the principal valleys; areas of marble, such as those forming the Texas, Dulaney and the Green Spring valleys, would be obtained by one stream system, while resistant bands, such as the serpentine strip east of Sykesville, would form marked ridges and divides. Such unadjusted courses as that of the lower Big Gunpowder which flows indifferently through granite-bound gorges or broad, marble valleys, or that of Gwynn's Falls which, flowing out of the gneiss, crosses the end of the long tongue of the Green Spring valley marble and turns back into the gneiss again without developing even a fair-sized subsequent along the marble, would not develop under the conditions of a normal cycle.

In general, normally adjusted and accordant drainage lines from the Potomac to the Susquehanna would have located the main divide of the Piedmont along a line running northwest from Baltimore. Secondary divides running northeast and southwest at either end of the main divides would be demanded by the streams flowing into the Monocacy and the ocean. This arrangement with its numerous trellised streams, Fig. 9, would be very different from the present plan in which the main divide runs northeast and southwest and the principal drainage lines are southeastward, while the stream patterns, instead of showing the results of adjustments, pursue random courses which branch in tree-like patterns across hard and soft rocks alike. The question naturally arises, Why do the streams show so little regard for the structure of the province?

Causes of Present Discordances.

It appears impossible to explain this discordant drainage by appealing to any of those ordinary phenomena which accompany uninterrupted stream development. The streams under discussion are entrenched to a depth of from one to three hundred feet below the general upland surface of the plateau. If they originated upon this upland, and are now sunk below it simply as the result of uplift, then they should now exhibit the trenched but well adjusted courses of streams which have attained to Maturity, for that was the stage

in the topographic cycle reached by the upland before it was given its present elevation. Since it is inconceivable that they could have developed such courses upon the Piedmont rocks under normal conditions, it is necessary to conclude that the present drainage lines were developed upon some other surface under other conditions and that the pattern thus independently produced has been impressed upon the Piedmont in spite of its lack of accord with the structure of the latter area.

The development of drainage along lines independent of the structure of the deeper rocks beneath it is not an unknown phenomenon, although it is not often reported. Those portions of the earth's surface which were the seat of widespread glaciation during the Glacial Period, namely, northern North America and Europe, had their pre-glacial topography more or less completely marked by the deposits which the retreating ice sheets left. Upon this new, constructional, glacial topography new streams of a peculiar kind have originated, and pre-existent rivers have either been blotted out or been materially modified in courses and directions. As the new or modified streams cut down through the glacial drift they have encountered the underlying rocks and have established their courses upon them. These courses, however, having been assumed on the glacial cover are independent of the subjacent structures and their newness is evidenced by the unreduced ledges which cause the many falls and rapids of the streams within the glaciated districts.

The famous cataracts of the Nile are due to the fact that the river, cutting down along a course taken on the surface of Cenozoic deposits, has reached a completely buried, irregular surface of granitic rocks. The Nile first took its course along the slopes of the uppermost rocks. Later, when revived by a geologically recent uplift, it deepened its channel until the granitic ledges became barriers to further downward cutting at those points. A very similar case is that of the rapids in the Grand Canyon of the Colorado. The Paleozoic and younger strata forming most of the canyon walls buried beneath them the Archaean gneisses and granites which the Colorado has now uncovered after cutting down through the softer mantle.

In all of these cases the streams are more or less closely following the courses which they established upon a cover of overlying rocks. After sufficient time has elapsed the covering strata were removed and the streams remain following discordant courses across the older and once buried rocks. There is good evidence in the outliers remaining to show that the eastern portion of the Piedmont Plateau was formerly partly buried beneath a mass of sediments belonging to the Coastal Plain. Similarly, in the western division, the stratigraphic conditions of the main body of the Newark formation and the scattered positions of remnants and gravels of the same indicate that these deposits once stretched over considerable areas of the limestones and phyllites now exposed to view. The thicknesses of both series of rocks were sufficient to quite mask the buried topography and give surfaces entirely independent of the former ones. It is apparent, then, that the conditions necessary for the development of drainage along lines independent of the structure of the Piedmont Province have existed in Maryland. These conditions obtained immediately antecedent to the present, and there is every reason to suppose that they were the controlling factors in the development of the present discordant drainage. On the east the irregular branching of the eastward flowing streams closely resembles the general pattern of the streams of the Coastal Plain province, compare Plates V and VIII, while the general southeastward direction of their channels is in accordance with the general dip of the Coastal Plain surface and strata. On the west the same wandering courses characterize the Monocacy and its tributaries, where they cross the metamorphosed or semi-metamorphosed rocks, as are to be found upon the yielding masses of the Newark beds. Moreover, if the Triassic rocks be restored over the areas whence they have been removed it appears that the Monocacy occupies a longitudinal position just where it would naturally develop if the elevation of the land was not sufficient to reveal the underlying rocks.

More detailed evidence of the origin of the Piedmont streams will be found in a special study of that problem given below. This shows that the streams, after developing courses which were characteristic

FIG. 1.—PATAPSCO VALLEY AT THE MOUTH OF BRICE'S RUN, BALTIMORE COUNTY.

FIG. 2.—PATAPSCO VALLEY AT ILCHESTER, ON BALTIMORE AND OHIO RAILROAD.

of Coastal Plain streams, cut down through the Coastal Plain and Newark covers and impressed themselves upon the underlying structures. They thus belong to the class of superimposed rivers. Examples of such drainage from other portions of the world have been cited above, but they are not lacking from districts nearer home. In Texas[1] streams and topography have been found which show signs of similar superposition from the blanket of the Coastal Plain sediments. In Connecticut[2] the lower course of the river of the same name departs at Middletown from an easy course along the Triassic sandstones, and turning to the southeast enters a deep gorge in the gneiss, which it follows to Long Island Sound at Saybrook. This aberrant position is attributed to superposition from the surface of a former northern extension of the Coastal Plain whose nearest representatives are now found on Long Island.

GENERAL TOPOGRAPHIC HISTORY OF THE PIEDMONT PLATEAU.

Reviewing the topographic features of the Piedmont Plateau, the succession of events and the stages in the topographic evolution of the province may be briefly summarized as follows: After the cessation of those movements which folded the sediments of the western interior seas into the Appalachian mountain system and raised them higher than the eastern crystalline land areas whence the sediments had been derived, the Piedmont district was slightly depressed and long shallow bays were formed in which the muds and sands of the Newark formation were deposited. How much time this required cannot be ascertained; but long before the end of Jurassic time these sediments had been consolidated, the bays drained of their waters, and the strata uplifted and broken into a multitude of blocks. Volcanic action also had forced in between the strata sheets of heavy dark-colored lavas. Then came a long period of terrestial quiescence during which the broad, even expanse of the Schooley peneplain was stretched across the variously arranged rocks of the Piedmont and

[1] Tarr, R. S., "Origin of some Topographic Features of Central Texas," Amer. Jour. Sci. (3), 1890, xxxix, 306-310. "Superimposition of the Drainage in Central Texas," ibid., xl, 359-361.

[2] Kummel, H. B., "Some Rivers of Connecticut," Jour. of Geol., 1893, i, 371-393.

the Appalachian regions. This peneplain probably extended fifty to one hundred miles beyond its present eastern boundary. This period of quiet ceased in late Jurassic time, being brought to a close by a slight elevation which permitted the fashioning of small limestone valleys below the general surface of the eastern Piedmont portion. This elevation was of short duration and gave place to the strong eastward tilting which permitted the westward transgression of the upper Potomac formations and later groups.

After this the land oscillated up and down causing the series of submergences and elevations which are recorded in the various strata and unconformities of the Coastal Plain series. During most of these oscillations of the eastern portion, the plain beyond Parr's Ridge stood continuously above sea-level, and the rivers, steadily working on their valleys, reduced many of them very nearly to base-level, leaving the ridges and mountains between to indicate the former higher altitude of the country as a whole. As these base-leveled valleys were produced during Tertiary time the general plain to which they were reduced, now 500 feet above tide, is called the Tertiary peneplain. At the close of Tertiary time a movement of the lands bordering the west permitted the sea to rapidly transgress upon the Piedmont Plateau almost to its western limits.[1]

The blanket of soil, which had been produced by long exposure to the atmosphere, was rapidly and incompletely worked over into the Lafayette formation and spread out as a thin mantle of irregularly stratified gravels, sands and clays. Again a period of elevation and erosion came on, during which deep gorges were cut in the Piedmont Plateau by the streams which originated on the Lafayette surface. Large areas of Lafayette materials were stripped from the surface of the crystalline rocks and carried down into the stream valleys. Along the Monocacy valley this elevation initiated the cutting out of the second terrace, which lies below the upper floor or Tertiary peneplain level.

The post-Lafayette elevation and period of erosion was followed by a number of oscillations which are recorded in the various deposits

[1] Concerning the extent of this transgression, see chapter on the Coastal Plain, p. 77.

of Pleistocene age. Pleistocene time closed with a decided elevation of the Maryland Piedmont Plateau causing the streams to trench their valleys, and to cut narrow gorges in the underlying gneisses and other foundation rocks. Although the streams west of the Fall Line are still at work reducing their channels, the portions of their valleys which are east of this line have, after this elevation, in common with the Coastal Plain, been depressed and converted into estuaries.

ECONOMIC PHYSIOGRAPHY.

In studying the Coastal Plain the physical features of that province were found to exert considerable control over the industries and habits of the people. The topography of the Piedmont Plateau has likewise influenced the settlements and the occupations of those who chose this region for their home.

Soils.

The early settlers, having to raise all their food, naturally sought out the best locations for their broad farms and beautiful estates. On their arrival they found two general classes of farmlands.

The first class embraced the somewhat rolling but extensive tracts of the interstream upland areas. The soils were found to be good producers of corn, wheat and grass, and the surface not so rough as to make its cultivation forbiddingly difficult. The long continuous tracts of these interstream areas also made traveling easy as long as one stayed on the upland, while the stream valleys were shut in and narrow. For these reasons, probably, the various stately manor lands were laid out where the upland expanses were greatest; and the mansions surrounded by fine groves and broad fields were located on the most promising of the small plateaus. In the earlier days the crops from these broad upland farms were among the richest in the state and rivaled those of the Eastern Shore.

The second class of farmlands comprised the alluvial loams and sandy flood-plains along the streams. These lands are generally restricted in area, since the valley bottoms are usually narrow and limited in extent. Where streams have opened out lowlands on the marble and limestone lenses rich lands of considerable extent offer most favorable farm sites. The lands along the streams have the

advantages of running water and good springs from the hillsides, they are not as well drained, however, as are the lands of the upland, and they are subject to damaging floods. Comparatively few settlers chose the valley lands at first.

A marked exception to the above rule is found in the Monocacy valley, where the farmlands are all located on the several benches and terraces leading down to the river or on the low bottomlands belonging to it. So little of the old upland is left that the conditions of occupation are quite different from those farther east.

Streams.

While the farming class were searching for good soils and favorable homestead sites, the manufacturers and millwrights were seeking favorable locations for mills, dams and flumes. The streams of the Piedmont Plateau yielded a great abundance of water-power, and soon mills dotted the valleys. Each section early came to be supplied with its grist mill, and in due time cotton mills were also built. These industries in time became of great importance. The flour mills are now generally abandoned, however, only a few of the most favorably situated ones having been able to maintain themselves against western competition. The cotton mills have held out much better, because it has not been until recent years that southern cotton has been spun and woven at home.

The water-power which the Piedmont streams furnish is not the only wealth which they bring to the state. The land movements during late geological time have caused the streams to trench their courses considerably, and in so doing have rendered accessible the building stones which were previously hidden beneath the surface. The granite now extensively quarried at Port Deposit would not be so easily obtained and shipped had not the Susquehanna river cut its deep gorge. The locations of the serpentine quarries of Harford county are determined to a greater or lesser extent by the streams which intersect the rock. A formerly important soapstone quarry on Winter run in the southeast corner of Carroll county was made possible only through the fact that the stream had there cut a deep gorge in a long band of steatitic serpentine. Along the Patapsco and Jones'

Falls many quarries of granite and gneiss have been located, because the stream gorges offered favorable openings or transportation facilities.

It is interesting, by way of contrast, to compare the different conditions under which the Cardiff-Delta slates are quarried. As no stream cuts across Slate Ridge in the vicinity of those two settlements, the quarries have been located along the summit and are worked entirely from above. This is the most difficult way to attack the slates, and as there is no natural drainage for the quarries, the water which is constantly accumulating in the pits greatly increases the cost of working.

Lines of Communication.

The valleys and ridges of the Piedmont Plateau furnish excellent examples of the way in which topographic features influence commerce and human activities.

One of the first acts of the early settlers of the Piedmont region was to lay out highways. These early roads were not always located advantageously with reference to the topography, but both the divides and the valleys were extensively employed. When the better turnpikes came to be built, however, they were almost without exception built along the divides. The reason for this was that fills and bridges were thereby avoided and better drained roadbeds, not subject to floods, were obtained. Radiating in all directions from Baltimore, these old pikes may be followed into almost every corner of the state, and their location on the more elevated ridges enables the traveler to obtain beautiful views of the richly wooded, rolling upland and tree-filled valleys.

With the advent of the canals and railroads more even grades were demanded and sought for. They were found by following the larger valleys.

The canals were built to overcome the obstructions to navigation which the Fall Line rapids occasioned, even in the larger streams such as the Susquehanna and the Potomac.

One of the early canals was the Susquehanna Canal, built along the east shore of the Susquehanna river in order to transport mer-

chandise from the limits of navigation at Port Deposit northward along that stream to the Pennsylvania line. This canal has now wholly fallen into disuse.

Another early and successful canal was constructed around the Great Falls by the Potomac Company. To obtain the necessary water and the most favorable grades this channel, now part of the Chesapeake and Ohio Canal, was laid out along the north bank of the Potomac, taking advantage of the natural trenches cut by that river. This canal was long the cheapest and best means of transportation between the coal and wheat lands of Allegany county and tidewater.

Since the era of railway construction began every advantage has been taken of the topographic features of the country. The Baltimore and Ohio Railroad crossing the Piedmont Plateau from tidewater found an easy exit from the depression about Baltimore and a gentle though crooked grade to the crest of the divide by following up the South Branch of the Patapsco river to Mount Airy and then along the Monocacy drainage to Point of Rocks.

The Western Maryland Railroad striking north and then westward could not utilize the lower course of the North Branch of the Patapsco on account of its narrow valley and very crooked channel. By following the broad, well-graded valley of Gwynn's Falls (see Plate XIX, fig. 2), as far as Emory Grove, however, an easy descent was found into the more favorable upper course of the North Branch of the Patapsco and thence an easy grade led to the sag in the divide at Westminster. A branch of the Western Maryland road running north from Emory Grove follows the Gunpowder-Monocacy divide as far as Manchester.

The Northern Central Railway enters the state from the north by following down the main branch of the Big Gunpowder and does not leave this stream until at Phoenix Mills the broad marble lowlands about Cockeysville open out and offer an easy crossing to the valley and gorge of Jones' Falls, which it follows down to Baltimore from Lake Roland.

A striking example is afforded by the Baltimore and Lehigh Rail-

way which takes advantage of the gorge of Deer creek to penetrate Rocky Ridge. Were it not for the aid thus rendered by the creek the engineers of the road would have been obliged to tunnel through the obstruction or else have gone a number of miles out of a direct course. Deer creek would not have been located across the quartzite and so could not have cut the gorge had it not accidentally taken this position while flowing on the Coastal Plain covering from which it was superimposed upon the quartzite. Besides the railway a county road also utilizes this gap and there are reasons to suppose that before the advent of the white man the Indians also used it as a thoroughfare.

In conclusion it appears that the topography has very materially controlled the settlement and economic development of the Piedmont Plateau by determining the location of the farms, the mills, and the railroads.

The Appalachian Province.

BOUNDARIES OF THE PROVINCE.

The Appalachian Province of Maryland embraces what is commonly known as Western Maryland. The eastern boundary of the province is formed by Catoctin mountain, while the western limits are artificially confined by the western boundary of the state, although topographically and structurally the province continues westward until it merges gradually into the lowlands of the Ohio drainage. To the north and south the topographic features of the province reach far beyond the limits of our state. The broad lowland of the Great Valley and the many parallel even-crested ridges with intervening valleys, which are so characteristic of the province, extend from central Alabama and Georgia northward through Maryland and then across Pennsylvania until they disappear in the plateau country of southern New York.

General Topographic Features.

The topography of the Appalachian Province is more varied, more picturesque and grander than that of either of the other two provinces. In its eastern part the broad and somewhat serrated crests of the Blue Ridge and Catoctin mountains overlook the broad, gently

rolling floor of the Cumberland or Hagerstown valley, which is watered by Antietam and Conococheague creeks, streams of some size that have sunk meandering trenches to depths of seventy-five or eighty feet below the general level of the valley floor.

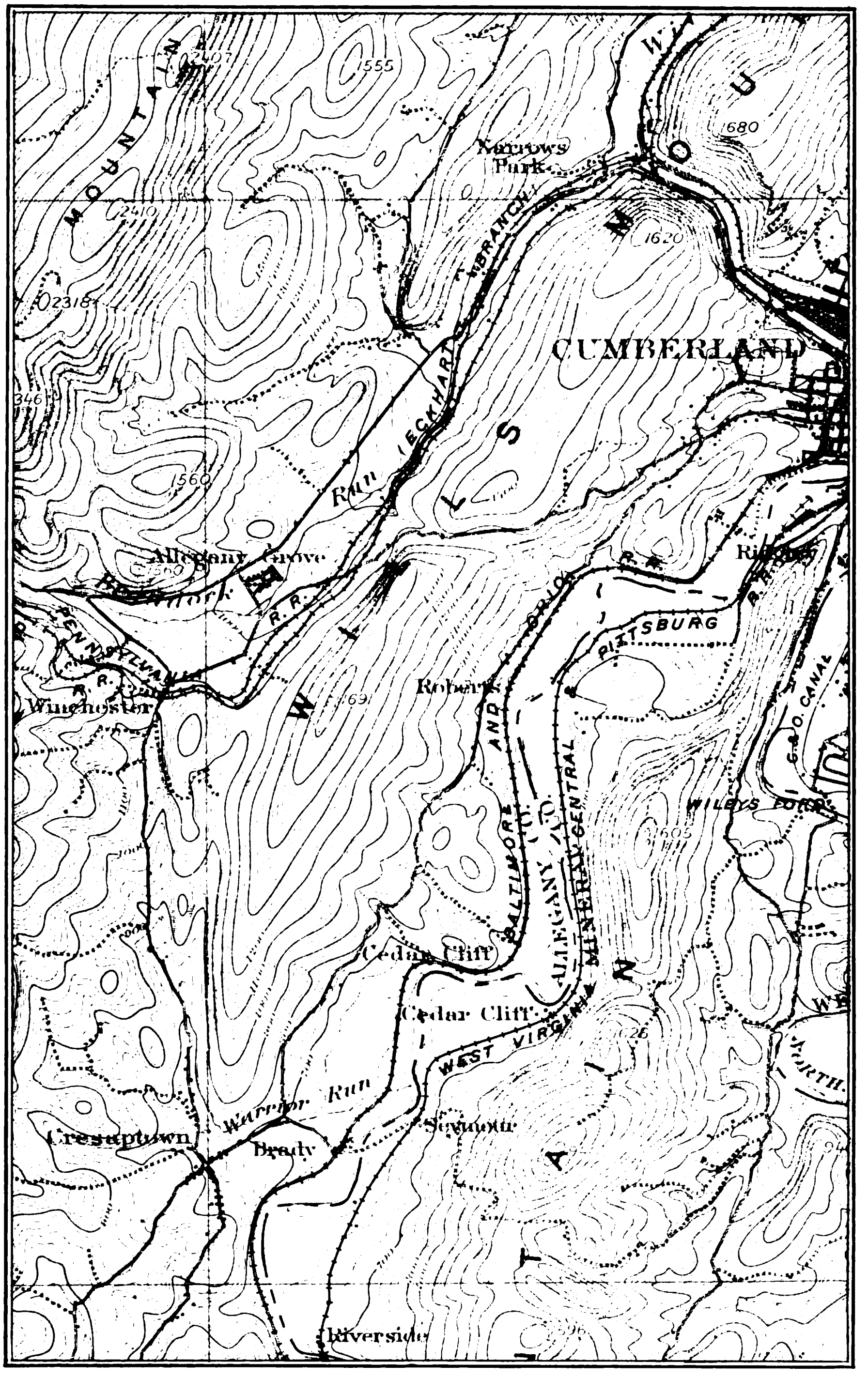
Beyond the Great Valley may be seen the long, even crest of North Mountain. This strongly marked topographic feature is the most easterly of a series of long, parallel mountains running northeast-southwest and alternating with long, narrow valleys. These ridges and valleys are the chief topographic features of the district between the Great Valley and Dan's Mountain west of Cumberland. They are termed the Appalachian Ridges and have been classed under that name as one of the sub-provinces of the Appalachian Province on the Outline Map, Plate III. Beyond these ridges, which gradually increase in height westward, the general surface spreads out as an extensive upland or plateau with an average elevation of 2500 feet, from which low parallel ranges of mountains rise.

THE STRUCTURE OF THE PROVINCE.

Present Structure.

In describing the Piedmont Plateau it was pointed out that the topography was so closely related to the geology that a map could be made showing the amount of topographic influence which the various formations had exerted, although strongly influenced by the covering of Coastal Plain sediments. The Appalachian Province still more strikingly shows this relationship, since the winds, rains and rivers have been at work for ages etching out the mountains and valleys along the lines determined by the structure of the country. The hills and the mountains all indicate by their parallel arrangement and N.E.-S.W. trend that the resistant rocks cross the state in the same direction, while the valleys tell the same story about the location of the less resistant formations. Such an arrangement of ridges and valleys as characterizes the Appalachian Province might indicate a structure similar to that shown in Fig. 5, but an examination of the attitudes of the various strata shows that the actual structure is as reproduced elsewhere.[1] This cut shows that the strata have been

[1] Md. Geol. Surv. Rept., vol. ii, 1898, p. 59, fig. 6.



MAP SHOWING APPALACHIAN TOPOGRAPHY OF ALLEGANY COUNTY.

FROM FROSTBURG SHEET, U. S. G. S.

thrown into folds whereby at certain points hard resistant conglomerates and sandstones have been brought to the surface, while at other points they have been thrust deep down and only the more yielding rocks above them appear. Many of the smaller ridges and even elevations such as Wills Mountain, mark lines along which some hard, resistant stratum has been arched up. Such ridges have their general cross profile determined by the arched strata which maintain them. Other prominent ranges, such as the Blue Ridge, owe the elevated positions of their resistant rocks to great dislocations along which the rocks have been thrust up above their earlier positions.

Between the ridge-forming folds or anticlines there were originally valley-forming troughs or synclines, in which it is probable that the rains gathered and formed streams which would be classed as consequent. To-day a number of small streams occupy similar positions among the ridges and mountains of Washington county. It is not at all likely, however, that these present streams have inherited their courses from consequent ancestors. On the contrary, since the synclinal troughs are occupied by yielding shales, it is much more likely that the streams took courses immediately above their present locations during the time when this whole district was being reduced to the general surface of the Schooley or Cretaceous peneplain. During that period of erosion the summits of the present hard ridges appear to have acted as guides directing the streams to develop along the more easily eroded strata of the synclines. In many cases the arches of hard rock originally rose so high above sea-level that they were truncated by the broad, gentle surface of the peneplain, as it was gradually extended across the folds. The domes of rock were thus completely unroofed and their cores of softer rocks became exposed to the attacks of the elements. Guided by these easier paths, certain rivers extended their courses, not along constructional troughs or synclines, but along the axial lines of the arches or anticlines. Along the axis of a comparatively broad flat anticline in Garrett county the two branches of the Savage river have opened the broad depression lying between Savage and Meadow mountains.

Original Structure.

The gradual change from the much disturbed strata of Washington and Allegany counties to the almost horizontal arrangement of the same strata in the plateau districts of Garrett county and of West Virginia, serves to remind the observer of the original positions of these beds. The successive layers of finer and coarser materials, the remains of animals and plants, and the close resemblance between many members of the series and various deposits which may be seen forming to-day, all point to the conclusion that these strata were deposited in succession over the floor of some very ancient sea. These strata, now so crumpled and folded, must have originally been almost horizontally disposed, just as any series of layers of mud and sand at the bottom of a pond may be seen to have arranged themselves when, the pond being drained, a ditch is cut across its old bed. All the present dislocations of those ancient strata are the products of folding and faulting under compression, which came after the rocks were laid down as horizontal beds of clays, sands and calcareous muds at the bottom of the interior Paleozoic sea.

The Appalachian and the Coastal Plain Structures Compared.

The strata now forming the Appalachians were deposited in more or less close proximity to a shore or coast which lay along the eastern limits of that ancient sea. The general location of this ancient land area, as indicated by the sediments derived from it, seems to have been in the district now occupied by the eastern Piedmont Plateau and western Coastal Plain provinces. In the period during which the Paleozoic strata were deposited this province was a more or less lofty land area, whose rivers, flowing westward, carried down large quantities of detritus to the sea. As the amount of materials thus transferred from land to sea floor increased, the sea itself would have been largely filled up had not the lands beneath the sea gradually subsided. In this way there was accumulated the great series of Paleozoic strata which stretched far westward from the coast of that time.

If now the strata deposited in this Paleozoic sea are compared prior to their dislocation, with the present Coastal Plain series, several points

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GETTYSBURG GAP, FROM BLUE RIDGE SUMMIT.

ON THE WESTERN MARYLAND RAILROAD.

of resemblance, particularly as regards origins and relations to the mainland, may be pointed out. Both the Paleozoic and the Mesozoic-Cenozoic sediments were deposited in seas often comparatively shallow, but which, although constantly filling with new materials, were also for a while gradually deepening, thus continuing the period of deposition. Both series of sediments were derived not only from areas immediately bordering the respective basins of deposition, but also in part from precisely the same region, namely, the Piedmont district. These comparisons show that during long periods in geological history the Piedmont region has been supplied with a Coastal Plain.

TOPOGRAPHIC SUBPROVINCES.

It is clear from the general description of the Appalachian Province given above that a four-fold subdivision is possible on the basis of the topographic types represented. These subdivisions from east to west may be designated as The Blue Ridge, The Great Valley, The Alleghany Ridges and The Alleghany Plateau.

The Blue Ridge.[1]

The physiographic subprovince here designated by the name of the Blue Ridge includes the Blue Ridge proper, the Catoctin mountain and the district lying between them. Blue Ridge proper, which forms the western boundary of the subprovince, is a long, straight ridge with slightly uneven and knobby crest maintaining an average elevation of 2000 feet above tide level. It starts in Pennsylvania as a portion of South Mountain, passes southward through Maryland and, after declining somewhat on each side of the Potomac gorge at Harpers Ferry, rises again in Virginia to a somewhat lesser elevation. That portion which lies within the limits of Maryland owes its crest-line altitudes to the superior resistance of the Lower Cambrian or Weverton sandstone which reached its present elevation partly as the result of a great overthrust fault, partly through more recent elevations of the whole of the Appalachian district.

[1] The names applied to this topographic unit vary in the different states traversed. In Pennsylvania the entire range is *called* South Mountain, in Maryland, South Mountain or the Blue Ridge, and south of the Potomac the Blue Ridge. Keith has applied the general term Catoctin Belt.

Although subsequent denudation has carved numerous scars and slight sags in the crest of the Blue Ridge, except for the narrow defile of a small branch of the Antietam creek debouching at Leitersburg, the Ridge presents an unbroken crest from Gettysburg Gap on the north to the deep gorge of the Potomac at Harpers Ferry. The western slope of the Blue Ridge Divide has the greater relief since its summit rises about 1500 feet from the level of the Cumberland or Hagerstown valley. The contours of this slope are generally precipitous along its upper zones. Over the lower portion they become much softened, however, and grade into low, rounded foot-hills which mark the outcrop of a band of fissile shales, Harper's shale, lying between the quartzite and the limestone, Shenandoah. The eastern slope of the South Mountain, since this is the direction in which the capping sandstone dips, is much milder than the western face. It also presents less boldness of relief because the contrast between the sandstone and the volcanic rocks lying against it on the east is much less pronounced than is that between the sandstone and the limestone or the shales of the Hagerstown valley.

East of the Blue Ridge proper, and almost parallel with it, runs the straight and slightly undulating ridge called Catoctin mountain, which forms the eastern boundary of the Blue Ridge subprovince. Its prominence is due to the greater resistance of the heavy Cambrian quartzite, which has withstood the attacks of the elements more successfully than the rocks on either flank. Again it is with the Catoctin, as with the Blue mountain, that that slope, which descends to the yielding rocks of the broad valley lowland, is the longer and the more precipitous, while the opposite slope is the milder and the shorter. Here, however, the valley lowland is that of the Frederick or Monocacy valley carved out on the Frederick limestone and the Newark formation. This lies to the east of the ridge, while the shorter and milder decline forms the western slope.

The continuity of the ridge is interrupted only twice within Maryland. Both gaps are in the northern portion of the crest and are cut by the two tributaries of the Monocacy between which is situated the town of Thurmont. The more northern of these streams is the

larger and has cut such a deep gap through the crest that it serves for the passage of the Western Maryland railroad on its way across the range.

Turning now to the valley included between the two crests just described it is found that this portion of the Blue Ridge subprovince has a number of peculiar and interesting features. It attains its best marked and most characteristic development in the southern portion of the district, in the drainage basin of the Catoctin creek, and is less characteristically a valley in the northern half of the area which is drained by the Monocacy and Antietam tributaries. In spite of the fact that nearly half of the drainage basin of Catoctin creek is underlain by igneous rocks, like granite and quartz porphyry, and the remainder by the still more resistant Catoctin schist, the stream has reduced a considerable portion of its basin almost to a base-levelled state during a geologically recent period. Starting with an average elevation of about 500 feet over that portion of the valley lying along the Potomac the old valley floor, now appearing as even-topped remnants between the streams, may be traced northward a little beyond Myersville, where it has reached an elevation of about 750 feet. A considerable part of this rise is accomplished within the last ten miles, where it is accompanied by a decreasing degree of regularity in the character of the old valley surface. This gradual change in perfection of modelling is what would naturally be found to exist over the up-stream portion of an old valley, since the lower portions of a stream's course are always found to be reduced more perfectly and uniformly than are its up-stream limits. Beyond Myersville the traces of this old valley floor are quite lost if the feature ever existed there. Below the more or less even surface of what may be called the 500 feet level, the Catoctin and its tributaries have incised their channels to depths up to a hundred feet, according as they are farther from or nearer to the present local base level, the channel of the Potomac river. The cross-sections of the gorges, as well as their depth below the old level, are indicative of their relative locations. Beginning with the narrow V-shaped ravines of the most distant and youngest branches, the gorges gradually assume a cross-section shaped

like a U. This form is characteristic of the lower course of the main stream and of the larger branches. It indicates that the streams have progressed beyond the stage in which vertical down-cutting is predominant, and have reached a point where the weathering of the canyon walls furnishes material somewhat in excess of the stream's ability to transport it. Above the general 500 feet level there remain a few areas not wholly reduced. These are more numerous along the sides and particularly at the head of the basin where they gradually merge with that portion of the area which never was reduced to the 500 feet plain.

The northern portion of this district, lying between the crests of South Mountain and Catoctin, seems never to have been reduced to such a valley lowland as formerly existed along Catoctin creek. The reason for this is evident. This portion of the area is drained chiefly by four or five streams already mentioned, all of which have to cut their way out across the refractory and practically insoluble quartzite before they can begin to work on the almost equally resistant epidote-schist. In contrast to these difficulties stand the conditions governing the Catoctin creek drainage. This system is largely employed in draining the areas of granitic rocks and the quartz porphyries, both of which, on account of the considerable percentages of feldspar in them, yield more readily to the solvent action[1] of the ground water. Owing to this peculiarity of the various rocks, Catoctin creek which flows directly into the Potomac after traversing the granitic rocks has been able, both in the past and the present, to reduce the lower portion of its channel with comparative ease, and so retain a decided advantage over its opponents on the north. The combined action of the resistant rocks to the north, and the superior powers thus possessed by the headwaters of Catoctin creek working up from the south has, so far, resulted in confining the drainage of the northern streams within comparatively narrow bounds. Although the volumes of the latter streams have thus been limited to such meagre proportions, small subsequent streams and valleys along the comparatively yielding quartz-porphyries have been developed, and to-day there may be seen green, level-floored, narrow valleys wind-

[1] Keith, A., U. S. Geol. Surv., 14th Ann. Report, pp. 310, 378.

FIG. 1.—THE POTOMAC AT WILLIAMSPORT, ON WESTERN MARYLAND RAILROAD.

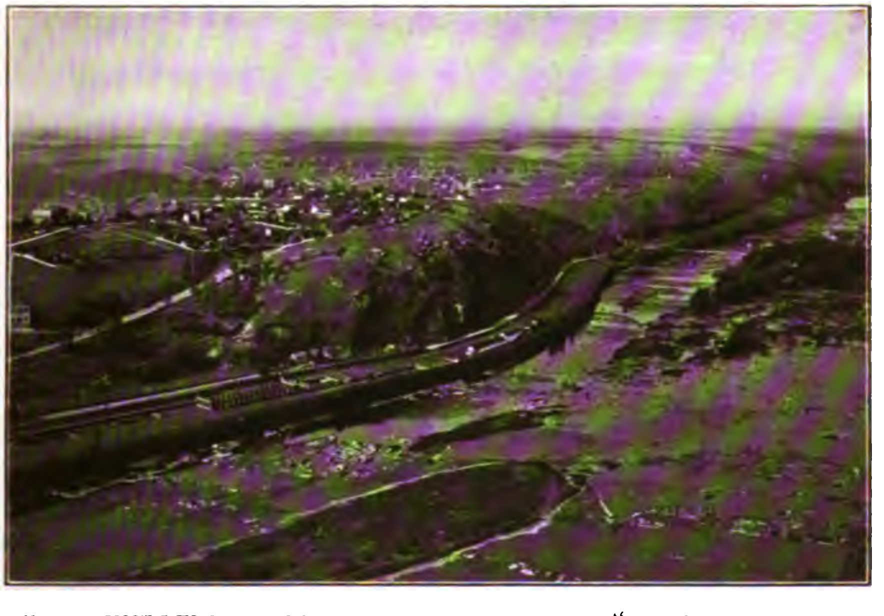


FIG. 2.—VIEW FROM MARYLAND HEIGHTS, SHOWING "THE GREAT VALLEY" IN THE DISTANCE.

ing in and out among numerous bluntly conical hills or long ridges. Below these valleys, particularly near the mountain fronts, the torrent-like streams have often cut steep, wild gorges.

The Greater Appalachian Valley.

The Greater Appalachian Valley,[1] or as it is sometimes called, the Greater Valley, embraces all the country lying between the Blue Ridge on the east and Dan's Mountain or Alleghany Front on the west, and thus has a width of about 73 miles. As has been noticed above, the Greater Valley admits of a two-fold division into the Great or Cumberland Valley on the east and the zone of Alleghany ridges on the west.

The Great or Cumberland Valley is the rather broad, even depression lying between the Blue Ridge on the east and North Mountain on the west. This broad, fertile valley, sometimes known as the Hagerstown Valley where it passes through Maryland, is a marked, topographic feature throughout the whole extent of the Appalachian province. The sharp contrast which it makes with the surrounding ridges is well shown by the model which was constructed for the Cumberland Valley Railroad and is here reproduced as Plate XIV.

The principal topographic feature of the Great Valley is its broad, gently rolling floor. Although this floor is now much cut up by minor drainage lines, its formerly almost level surface has given the present hills very strikingly accordant elevations. So nearly coincident are the various heights that, if a flat board floor could be laid across the valley it would be supported by almost every hill and would have an altitude of about six hundred feet above sea-level. Long divides with broad tops maintain this average elevation over considerable distances, and are generally occupied by highways. There is a slight descent from the northern boundary of the state to an elevation of from 500 to 550 feet along the Potomac, which brings this former plain into relation with the plain along the Catoctin creek and the Monocacy river. Southward from the Potomac, however, this plain rises as it follows up the Shenandoah valley, finally reaching a maximum elevation of 1700 feet in southern Virginia. The pho-

[1] B. Willis, The Physiography of the United States, 1896, p. 169.

tograph forming Plate XIII, fig. 2, illustrates the general character of this valley floor in the vicinity of the Potomac.

The principal streams draining the Maryland section of the Great Valley are Antietam and Conococheague creeks, both of which rise in Pennsylvania and flow southward through Maryland to the Potomac. The valleys of these streams are deep, narrow and steep-sided, that of Conococheague creek being particularly gorge-like in character. The streams themselves are rather rapid and have not yet reduced their channels to even grades, as is shown by the low ledges of shale or even limestone which sometimes interrupt their flow. The courses of the channels are tortuous, often quite meandering, and the turns and twists of the channels are always followed by the gorge walls. This fact indicates that the streams originated their meanderings on the flood-plains which accompanied them when the present dissected valley floor stood at a lower elevation and these streams flowed upon its continuous surface. As the area was elevated the streams began to cut down along their courses, always keeping a little behind the Potomac as it deepened its channel. Thus the winding courses which the streams followed on their earlier flood-plains became impressed upon the limestone and shale beneath, and these more resistant rocks still retain the streams in their old courses which are described as *inherited* or *superimposed.*

The general characteristics of *the Alleghany Ridges* have already been briefly sketched. Several of these ridges are due to the uparching of resistant sandstones which have withstood the attacks of the elements, while the yielding rocks which covered them have given way. The best examples of such prominences are found in Wills Mountain, Martin's Ridge, Warrior's Ridge and North Mountain. The dome of the arch in the latter case has been partly removed, however, and the yielding shales beneath which were formerly protected are now rapidly giving way. There is thus forming a shallow and elevated valley along the axis of the uplift. All of these mountains rise very nearly if not quite to the 2000 foot level.

Other crests, such as those of Town Hill, Sideling Hill and Tonoloway Hill, fail to reach this height by about five hundred feet.

They owe their elevation to the fact that, in a number of cases, the Carboniferous conglomerate or sandstone was depressed below the general level of the Schooley peneplain, and thus escaped being worn away during the production of that feature. Subsequent elevation and erosion have removed the softer rocks, which are then exposed by the unroofing of the arches or anticlines and these small synclinal remnants of the hard sandstones now stand out in relief as protecting caps to the yielding strata just beneath them. Thus what was originally a series of constructional synclinal valleys has been converted into a set of parallel, even-crested ridges with synclinal summits.

Between these mountains and ridges comparatively broad, even-floored valleys were at one time carved out by the streams which had breached the anticlinal arches during the Mesozoic era. For so long a time did the land stay at rest after the elevation of the Schooley peneplain that these streams reduced their valleys to very gentle slopes, even far back in among the ridges. Sufficient time, however, was not allowed for their reduction of the ridges, also, as was the case during the preceding cycle. It was at this time that the level floor of the Great Valley was produced, the general surface of which can be followed in and out among these western ridges. This generally even and accordant surface is often referred to as the Shenandoah Plain, because it is so typically developed over the yielding rocks of the Shenandoah valley. Having been developed only in the vicinity of the streams, the Shenandoah Plain is found to rise gradually as it extends towards the headwaters of the various mountain streams of the central district. The general elevation, however, is found to be somewhat greater and the inclination of the surface steeper than would be the case if due simply to the normal stream slope of the region. These features are believed to be due to a general and unequal elevation of the land after the Shenandoah Plain had been developed. This elevation, or more strictly speaking, warping, was greatest along a northeast-southwest axis located near the eastern boundary of the Alleghany Plateau, and also along a minor axis running southwestward from southern Virginia and West Virginia, the influence of which was extended as far

northward as Maryland and eastward to the Atlantic coast line, affecting to some extent the district of the Alleghany ridges.[1]

This warping of the Shenandoah Plain exerted a marked influence upon the development of the well-adjusted streams of the Appalachian district which, at the close of the period of denudation, were meandering over comparatively broad flood-plains. The elevation which succeeded the period of denudation revived the activities of the streams, and they rapidly deepened their channels, cutting narrow winding courses, taken from their former directions on the Shenandoah Plain. Continued denudation has now worn away considerable portions of the inter-montane region, so that its general surface can be traced only in the long, flat inter-stream areas and the rounded crests of those hills which rise to the general level of the plain.

Among the most characteristic remnants of this formerly extensive surface may be mentioned Shriver's Ridge, with an elevation of 1071 feet, the northern spur of Knobbly Mountain across the Potomac river with an elevation of 1115 feet, the heights northeast of Cumberland with an average elevation of something over 1000 feet, and the broad, dissected district extending northward from Old Town, which is drained by Big Spring run and Town Creek, with an average elevation of about 900 feet. The character of the gorges which the streams have cut below the uplifted Shenandoah Plain clearly shows that the rate of elevation was not uniform. At least three distinct terraces can be made out along the banks of the Potomac in the vicinity of Cumberland. Each terrace indicates a period of temporary quiescence for the land, during which the stream was able to expend some of its energy in the horizontal cutting and widening of its channel; while each slope from a higher to a lower terrace indicates renewed activity in vertical down-cutting. The two upper terraces belong to the class of *stream-cut terraces*, as is shown by the fact that their almost horizontal tops are bevelled across the upturned shales. Only a very thin layer of scattered cobbles and gravels is found on either terrace. The lower terrace is so heavily

[1] Hayes, C. W., and Campbell, M. R., Nat'l Geog. Magazine, vol. vi, 1894, plate 6.

VIEW OF MODEL OF THE BLUE RIDGE AND THE GREAT VALLEY, TRAVERSED BY THE CUMBERLAND VALLEY, WESTERN MARYLAND, BALTIMORE AND OHIO AND NORFOLK AND WESTERN RAILROADS.

(PUBLISHED BY PERMISSION CUMBERLAND VALLEY RAILROAD.)

covered with river deposits of sand, gravel and boulders that it is difficult to say whether it is a *cut* or a *built* terrace or a combination of both. These terraces, particularly the two lower ones, may be followed down the Potomac beyond Harpers Ferry running in and out of the stream valleys which join that river from either side and gradually declining in elevation. Up-stream they have been traced as far as Keyser and undoubtedly extend a considerable distance further. Attempts have been made [1] to correlate these terraces with contemporaneous epochs of deposition contained within the Coastal Plain series, but very recent work in that group of deposits by the New Jersey and Maryland surveys has so altered former conceptions of stratigraphic sequences and conditions of deposition that it seems best for the present at least not to attempt a statement regarding the stratigraphic equivalents of these features.

The Alleghany Plateau.

The Alleghany Plateau extends from northern central Alabama, where it is known as the Cumberland Plateau or tableland, northward and eastward through Tennessee, Kentucky, Virginia, West Virginia, Maryland and Pennsylvania into New York, where it forms the high lands covering the southern half of the state from the Catskills to Lake Erie. This plateau, which preserves, in its general level, the largest continuous areas of the Jura-cretaceous, or Schooley peneplain, is not characterized by a broad, unbroken expanse, but has been so deeply dissected that only the even crests of isolated ridges remain to indicate the former extent of the plateau. Standing on some lofty central point, such as the crest of Keyser's Ridge in Garrett county, one sees all about these long level-topped crests which seem to rise very nearly to the same general height, although there is a gradual decrease in elevation northward and eastward from the district between Savage Mountain and Keyser's Ridge. The long ridges are arranged in almost parallel ranks and follow the broad curves of the Appalachian system, while their even crests are the

[1] McGee, W J, "The Terraces of the Potomac Valley," *The Evening Star*, Washington, June 20th, 1885.

Keith, A., U. S. Geological Survey, 14th Ann. Report, 1892-93, pp. 285 et seq.

present representatives of that broad peneplain which has already been so often referred to in dealing with the eastern portions of Maryland. The most representative elevations of this peneplain are found in Savage Mountain, which has an altitude of about 3000 feet in Keyser's Ridge and Negro Mountain, with elevations of 3000 feet, in Winding Ridge 3000 feet, and Hoop Pole Ridge 2800 feet. These elevations are the culmination of the westward rise of the Schooley peneplain in the latitude of Maryland. Farther westward the general surface gradually declines to the Ohio and the Mississippi rivers. Within the Maryland portion of the plateau the strata are still gently folded, so that the extension across them of the old peneplain surface here also resulted in the removal of several rock domes. Thus, while the land was being reduced to very mild topographic forms, the way was being prepared for the easy carving out of lofty mountain ranges during a subsequent time. As a result of the elevations which have taken place since the Schooley peneplain was produced, the streams which had developed on that surface, and whose courses were adjusted to its underlying structure, have deepened their valleys very considerably. There were other streams, however, which, although they occupied courses located on yielding rocks, had carved their valleys out along synclinal axes and have not, since their elevation, materially deepened their valleys.

There are thus seen to be two classes of valleys and streams within the boundaries of the Maryland portion of the Plateau, one class has synclinal or consequent streams and valleys, the other class embraces the subsequent or anticlinal streams. The characters of the valleys of these two classes are quite as distinct as their relations to the structure. The subsequent streams have developed their courses generally along Jennings and Hampshire shales, which formed the cores of anticlines whose domes were the resistant Pocono sandstone. The elevation which interrupted further development of the Schooley peneplain gave all these streams increased activity and they began to actively reduce their valleys to the new base-level.

To-day the new valley-floors thus produced may still be seen as flat-topped hills of Hampshire and Jennings shales bounded by steep and

often precipitous cliffs which are capped by rocky crags of Pocono sandstone. Perhaps the largest area covered by this surface of denudation is to be found in the vicinity of Accident. This town is located near the center of a broad amphitheater, whose boundaries are the curving Pocono-capped crests of Winding and Keyser's ridges, and whose floor is a very gently rolling surface, large portions of which remain over the inter-stream areas. This is the old floor produced just after the elevation of the Schooley peneplain. Numerous disconnected areas along the northwestern flanks of the Savage river valley also preserve this surface. Turning to those streams which pursued consequent or synclinal courses, it appears that instead of occupying deep valleys with steep bounding slopes, their valleys are comparatively shallow and stand at higher levels than do the subsequent valleys. These consequent valleys are now lifted high above the other streams and present very slight contrasts in relief as compared with the other streams of the Plateau. The best example of this class of streams and valleys is found in the valley of the Castleman river. This stream is located on the portion of the Fairfax formation, or Barren Measures, which reposes in the synclinal basin between Meadow and Negro mountains. The valley is very broad and comparatively shallow, especially at the southwestern end of the syncline, and there is no sudden break in the slope from the crests of the two limiting mountains to the axis of the valley. The reason why the streams draining such valleys as that of the Castleman river have never been able to reduce those valleys successfully is due to the fact that the whole valley is floored with a resistant conglomerate or sandstone, which must all be removed before the mountain can be lowered. They are hemmed about by the same hard stratum, and the streams which have to cross it in order to leave the valley cannot remove the core of the anticline below the level to which they have cut down their outlet. It is, however, a much easier task to cut a gorge through a narrow ridge of the sandstone than it is to remove a broad, almost flat sheet of the same rock. Therefore, streams like the Savage have carved deeper and more sharply bounded valleys than have such rivers as the Castleman.

Just here it may not be amiss to refer to those broad, wholly enclosed valleys whose meandering streams are often bordered by rather marshy ground. Such valleys are known in Garrett county as *Glades*, while any valley which has steep bounding slopes and slightly marshy flood-plain is called "glady country." These poorly drained areas are calculated to attract attention in a district where the sharp relief of the country in general insures unusually well-drained soils. To one familiar with the poor drainage of the glaciated districts of the United States, glaciation [1] at once offers itself as an explanation of this topography. There are, however, none of the other signs of glaciation, such as transported boulders, striated ledges or morainic material. Moreover, it is possible to adequately explain the Glade Country by appealing to processes acting there at present and during the past. The following explanation, based on recent geological studies in the Glade districts, is offered by Mr. A. C. McLaughlin of the Maryland Geological Survey.

The typical Glades of Maryland are located on the strip of Jennings and Hampshire shales which lies between Backbone mountain and Hoop Pole Ridge in the vicinity of Oakland and Deer Park. This broad, gently rolling valley is drained by two rather sluggish streams known as North Glade run and Green Glade run, both of which unite beyond Hoop Pole Ridge to form Deer creek, a tributary of the Youghiogheny. Hoop Pole Ridge is a monoclinical ridge of Pocono sandstone which offers considerable resistance to erosion and has retarded both of the streams crossing it. While thus retarded at the edge of the Glades by this sandstone ledge, the headwaters of these streams have been working on the yielding shales until they have been reduced very considerably, in fact, quite to the level of the stream crossing on the sandstone. The stream grades are now so flat here that they cannot carry away the debris washed by the rains from the low shale hills. The result is that immediately along the streams the accumulation of alluvium has been so rapid that the stream is slightly choked and has thus become marshy. The Glades therefore are simply a well-reduced local base-level plain determined by the marked contrast between the yielding shale and the investing

[1] Gibbes, Geo., The Glades of Maryland, Amer. Nat., vii, 1873, p. 636.

barrier of resistant sandstone. It might be added that possibly the inability of the two streams to remove the alluvium may be due to decreased volumes, resulting from recent captures by the headwaters of the Savage or the Youghiogheny rivers, both of which have tributaries on the shales in the immediate vicinity of the Glades.

So far the Maryland streams of the Alleghany Plateau have been considered from their purely local relations. It is interesting to consider briefly their general relations to the broad structural features of the region. From this point of view also there are two classes of streams here; first, those which flow westward down the general dip of the strata to the Ohio, and second, those which flow eastward against the general dip to the Atlantic. The Youghiogheny and Castleman rivers take out all the Ohio drainage, while the Savage and the North Branch of the Potomac lead off the waters which flow into the Atlantic. It has already been pointed out that the whole Appalachian district formerly bore the relation of a coastal plain to a land area lying somewhere to the east. In view of this fact the rivers should naturally all flow westward down the inclination of the strata towards the old sea. As a matter of fact, only the Youghiogheny and the Castleman approach to this arrangement, while the Potomac and its tributary, the Savage, go in directly the opposite direction. They even do more, for they cut across what we can see of that old land area and empty into the Atlantic at a point where formerly there may have been high hills. To explain this anomalous course of the Potomac is one of the larger and more difficult problems for the physiographers of the Atlantic slope to solve.

GENERAL TOPOGRAPHIC HISTORY OF THE PROVINCE.

The topographic history of the Appalachian Province may be briefly summed up as follows. The Province originated as a coastal plain along the western shores of some ancient land area, part of which may be represented in the ancient crystallines of the Piedmont Plateau. Probably shortly before the close of the Paleozoic this coastal plain was elevated and deeply folded in its eastern portion by powerful compression. This elevated and corrugated coastal plain then suffered a partial reversal of its westward flowing drain-

age, and remaining for a great length of time in a quiescent state, was so far reduced by erosion as to present the features of advanced topographic maturity and perhaps even become a peneplain. This period of repose was closed by a decided warping of the new surface that raised it to an elevation of about 2000 feet in Western Maryland, but only to about 300 feet in the central portion of the state. Then followed another period of repose during which the Shenandoah Plain was carved out. Finally a series of elevations at irregular intervals has warped the two plains, still further bringing the Schooley peneplain level to altitudes of 3000 feet in the western and 500 to 800 in the central section of the state, while the Shenandoah Plain stands at 1000 feet to 1500 feet in the west and 500 feet in the east. The latest elevations have caused the streams to cut below the level of the Shenandoah Plain a series of steep, terraced gorges that they are still deepening.

ECONOMIC PHYSIOGRAPHY OF THE PROVINCE.

Lines of Communication.

The obstacles offered by the successive parallel ridges of the Appalachian province delayed the westward movement of the population in colonial days and restricted the east and west lines of travel to the valleys of the Potomac, the Susquehanna, and the James. The earliest inhabitants found these natural highways already selected as the lines of communication between the distant parts of the great Indian Confederacy, and accepted the experience of the aborigines by building their roads along the same lines.

As the population of the western portions of the state increased the demand for more perfect highways became urgent, so that before the end of the eighteenth century several well-defined lines of travel had been established between the tidewater regions along the Atlantic and the Ohio drainage. The Cumberland road extended from Washington to Cumberland via Hagerstown and Hancock, and thus followed the line of easiest travel along the valleys and across the divides at their lowest points. Beyond Cumberland the road was extended across Big Savage mountain and the Alleghany Plateau, keeping on the divide between the Potomac and Youghiogheny until it entered

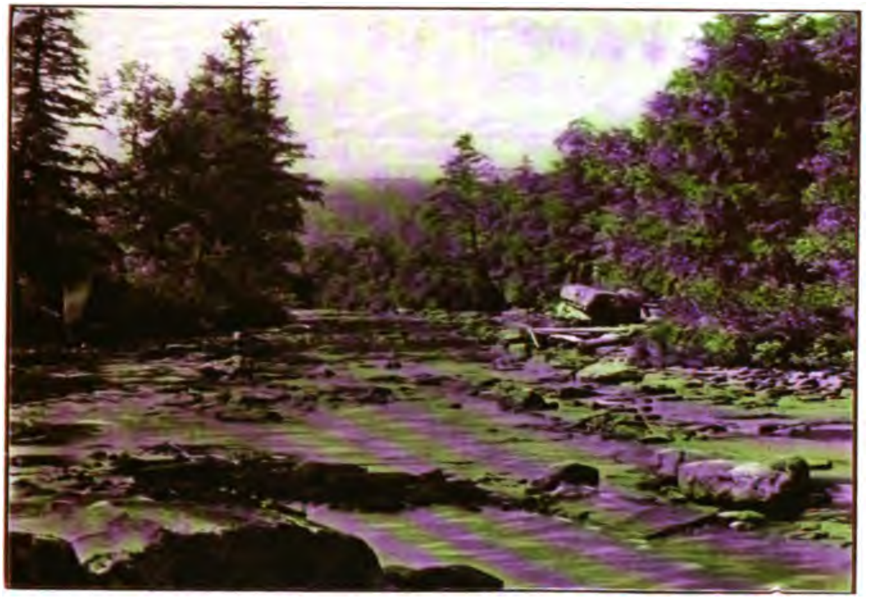


FIG. 1.—THE YOUGHIOGHENY NEAR OAKLAND.

FIG. 2.—THE YOUGHIOGHENY AT FRIENDSVILLE.

the valley of the latter, which it followed to the Monongahela, and thence down stream to Pittsburg.

Later the promoters of the Chesapeake and Ohio Canal gained the right of way up the Potomac valley, which is followed to Cumberland. The course of the Potomac at Harpers Ferry and Point of Rocks offered the easiest means of communication across the Blue Ridge district, and when once occupied the Chesapeake and Ohio Canal effectually stopped the westward progress of the Baltimore and Ohio Railroad along the same route until a compromise was effected in 1832. West of Cumberland the railroads crossing the state follow the valleys of the rivers, utilizing the courses of the Potomac river, Wills creek, Georges creek, Jennings run, the Savage river, and the Youghiogheny river.

Natural Resources.

The resources of the Appalachians are varied and valuable. The early settlers found the mountains clothed with dense forests of pine and hard wood, but they lacked the means for transporting the lumber to a ready market. Even now with a canal and several railroads the cost of hauling from the forest to the point of shipment is so great as seriously to reduce the profits of the lumbering trade.

The many varieties of soils in the Appalachians are closely related to the geological formations, and their distribution is clearly influenced by the geological structure. Since most of the higher hills and sharp ridges are due to the presence of heavy beds of siliceous sandstone, the soils of the upper slopes are generally sandy and poor. Beneath these strata come beds of shales which are sometimes calcareous, so that the lower slopes, hills and *subsequent* valleys contain soils which, while somewhat stony, give fair yields in wheat, corn, etc.

The Great Valley, with its rich limestone soil and easy means of access from the north and south, forms a broad band of the most fertile lands in the state. If it had not been for the re-elevation of the Shenandoah plain this district would be most favorable to farming. As it is, the rolling surface and steep valley slopes are somewhat difficult to till with ease. The land is so rich, however, that the whole stretch of the valley is or might be under cultivation.

The chief sources of mineral wealth in the province are the deposits of coal, iron and cement rock. The coal beds are the remnants of larger areas preserved by their depression below the limits of erosion during the formation of the Schooley peneplain. They have proved of inestimable value to citizens of the state. The Clinton iron ores were formerly very valuable, but in the present state of the iron market they are of relatively little importance. The cement rock is obtained from certain portions of the Silurian limestones and is the basis of a growing industry. The exposures are favorably situated along the lines of travel, so that the mills have every advantage for the shipment of their product.

Inhabitants.

The physiography, industries and resources of the Appalachian province have strongly influenced the character and occupation of the inhabitants, who may be grouped into several well-marked classes. In the higher more rugged and less populated portions of the area are the mountaineers, who gain their livelihood by lumbering and desultory farming. Gathered about the rich deposits of coal, iron ore and cement are miners, who are occupied almost exclusively in the extraction of wealth from the underlying rocks. They present a class of marked characteristics in education, training, religion and nationality. The valleys between the mountains, especially the Great Valley, and the larger more level areas of the glades, furnish incentive and opportunity for farming communities, which are reasonably well recompensed for their efforts in the tilling of the soil. In the cities and larger towns are concentrated those who serve as distributing agents for the products of the land and the necessities of the inhabitants.

The Development of the Streams of the Piedmont Plateau.

INTRODUCTORY REMARKS.

In 1888 Mr. W J McGee published a series of papers[1] on the earlier members of the Coastal Plain series, in which he interpreted

[1] McGee, W J, Three Formations of the Middle Atlantic Slope, Amer. Jour. Sci. (3), vol. xxxv, 1888, pp. 120, 328, 367, 448.

the geographic and topographic history of the regions by means of the sedimentary records. In this series he makes the statement [1] that "the former westward extension of the [Potomac] formation can be reliably inferred from the topographic configuration of the Piedmont region, the western part of which has a drainage evidently determined by lateral heterogeneity of the vertically bedded terrane and a characteristic topography resulting therefrom, while the eastern part has a drainage independent of the varying obduracy of the terrane and therefore evidently superimposed by a formation (which could only have been the Potomac) now generally removed by erosion." This statement is based on some work done several years previously upon the geology about the mouth of the Susquehanna river.[2] In this paper an epigenetic or superimposed origin for the streams of the eastern portion of the Piedmont Plateau was first proposed. As McGee did not give much detailed evidence in favor of this view, the writer undertook in 1895-96 the collection of details which are essential to the determination of its correctness. The purpose of this chapter is to set forth the results of the study thus inaugurated.

In 1889 W. M. Davis,[3] in his study of the Pennsylvania drainage, suggested that the discordant position of the lower course of the Susquehanna might be explained by supposing superimposition from a flood-plain contemporary and coextensive with the Potomac formation. Later in studying the rivers of New Jersey [4] he came to the conclusion that the locations of several small streams across the trap ridges of First and Second mountains were due to superimposition from a westward extension of the Coastal Plain sediments.

Only one other investigation of this nature has been conducted on the streams near Maryland. Miss Bascom [5] in 1897 published a short account of some discordant drainage near Philadelphia which is ex-

[1] Op. cit., pp. 133-134.

[2] McGee, W J, The Geology of the Head of Chesapeake Bay, U. S. Geol. Surv., VII Ann. Rept., 1885-86, pp. 545-644.

[3] Davis, W. M., The Rivers and Valleys of Pennsylvania, Natl. Geog. Mag., vol. i, 1889, pp. 241-242.

[4] Davis, W. M., The Rivers of Northern New Jersey, Natl. Geog. Mag., vol. ii, 1890, p. 99.

[5] Bascom, F., The Relations of the Streams in the Neighborhood of Philadelphia to the Bryn Mawr Gravel, Amer. Geol., vol. xix, 1897, pp. 50-57.

plained by superimposition from the cover of Potomac clays and gravels.

Beyond the limits of the Middle Atlantic Slope one or two important river studies have been executed which have some bearing on the Maryland problems. In 1890 R. S. Tarr[1] reported cases of streams in Texas which were superimposed from Cretaceous upon Paleozoic rocks; and H. B. Kummel,[2] a year later, suggested that the eastward deflection of the Connecticut at Middletown, where it leaves the yielding Triassic rocks and cuts a gorge in the crystallines, might be due to superimposition from the extended Cretaceous cover.

THE PROBLEM PRESENTED.

The observations of A. Keith, W J McGee, and others have shown that the gently rolling upland surface of the Piedmont Plateau is a continuation of the Schooley peneplain of New Jersey and Pennsylvania. The conditions of formation of a peneplain, or even of a district well advanced in topographic maturity, carry with them the expectation of finding the streams well adjusted to the underlying structure. Since the streams of the Maryland Piedmont region are found to be unconformable to such conditions, the question arises, as to what is the cause of this discordance.

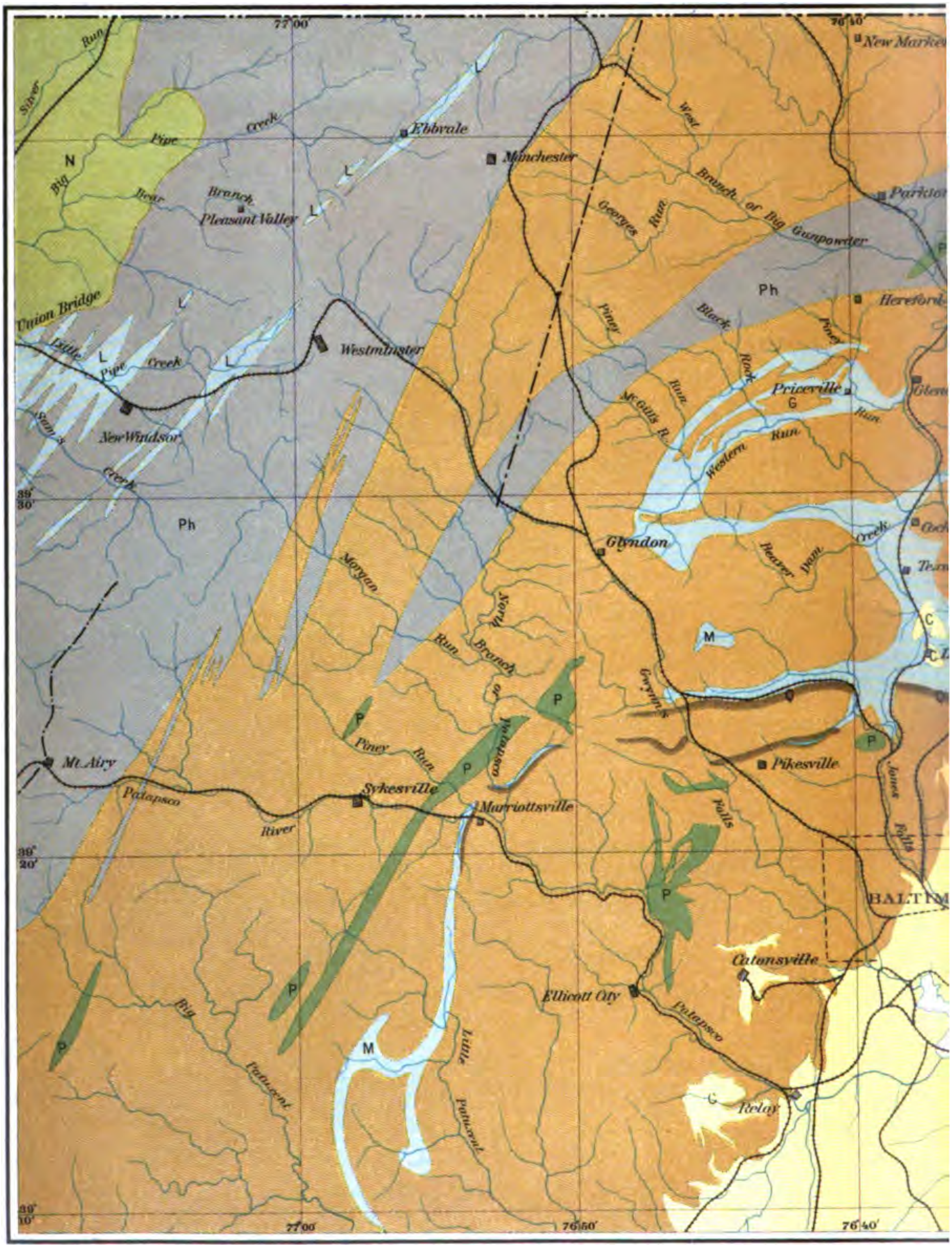
The proximity of the partially removed Coastal Plain sediments and the number of isolated patches of the Coastal Plain formations found lying beyond the general boundary of the latter province, seem to offer a ready answer to the question. This is the one suggested by McGee, viz. that the streams have inherited their present courses in large part from a previous cycle when they were located on the surface of the then more extensive Coastal Plain.

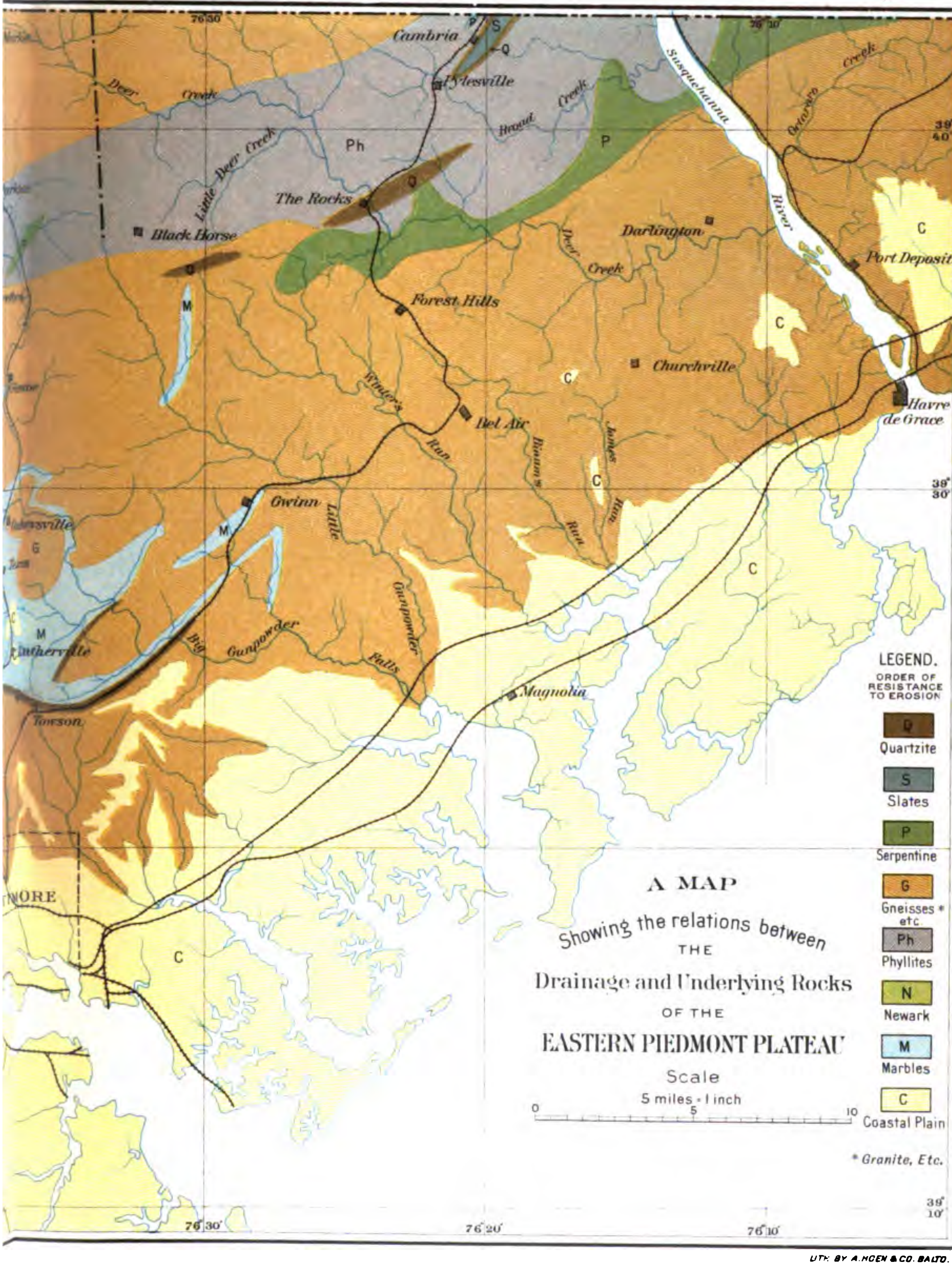
DETAILED STUDY OF TYPICAL STREAMS.

The succeeding detailed descriptions and studies of certain streams have been made with the threefold purpose of examining the evidence

[1] Tarr, R. S., Origin of some Topographic Features of Central Texas, Amer. Jour. Sci. (3), vol. xxxix, 1890, pp. 306, etc., and Superimposition of the Drainage in Central Texas, ibid., vol. xl, pp. 359-361.

[2] Kummel, H. B., Some Rivers of Connecticut, Jour. of Geol., vol. i, 1893, pp. 371-393.


77°00'
76°40'
New Market
Silver Run
Big Pipe Creek
Bear Branch
N
Ebbvale
Manchester
Pleasant Valley
L
West Branch or Big Gunpowder
Georges Run
Parkton
Union Bridge
Little Pipe Creek
Sams Creek
New Windsor
Westminster
Ph
Hereford
Piney
Black Rock
McGills R.
Run
Priceville
G
Western Run
Glyndon
Beaver Dam Creek
Morgan Run
North Branch or Patapsco
M
C
Gwynns
P
Piney Run
Pikesville
Mt. Airy
Patapsco River
Sykesville
Marriottsville
Falls
Jones Falls
39° 30'
39° 20'
39° 10'
BALTIM
Catonsville
Ellicott City
Patapsco
Big Patuxent
Little Patuxent
Relay
77°00'
76°50'
76°40'



LITH. BY A. HOEN & CO. BALTO.

for and against the theory of superimposition; of finding, if possible, the topographic evidences which will indicate a former westward extension of the Coastal Plain blanket; and of determining the date or dates at which the streams may have been superimposed.

The systems of drainage described in the following pages are confined to the Eastern Piedmont Plateau and are represented upon Plate XVI. The area included in this plate is indicated by shading on the Index Map, fig. 15.

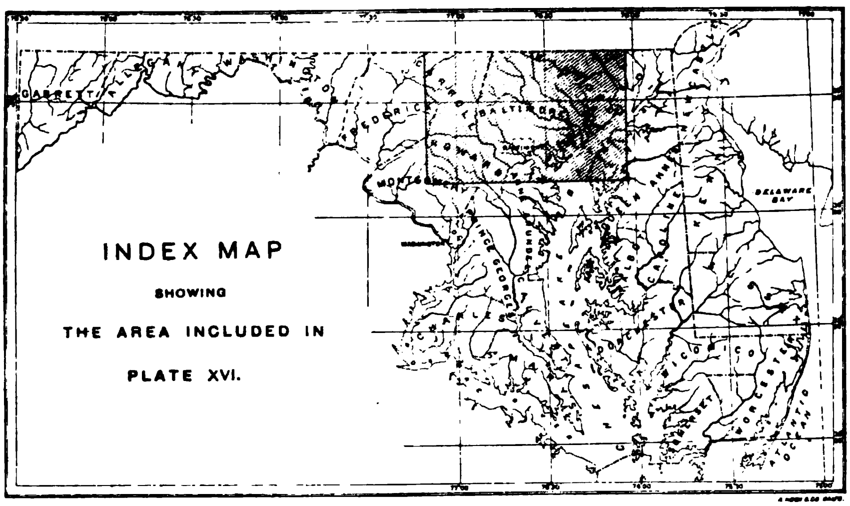


FIG. 15.—Index map showing location of Plate XVI.

Deer Creek.

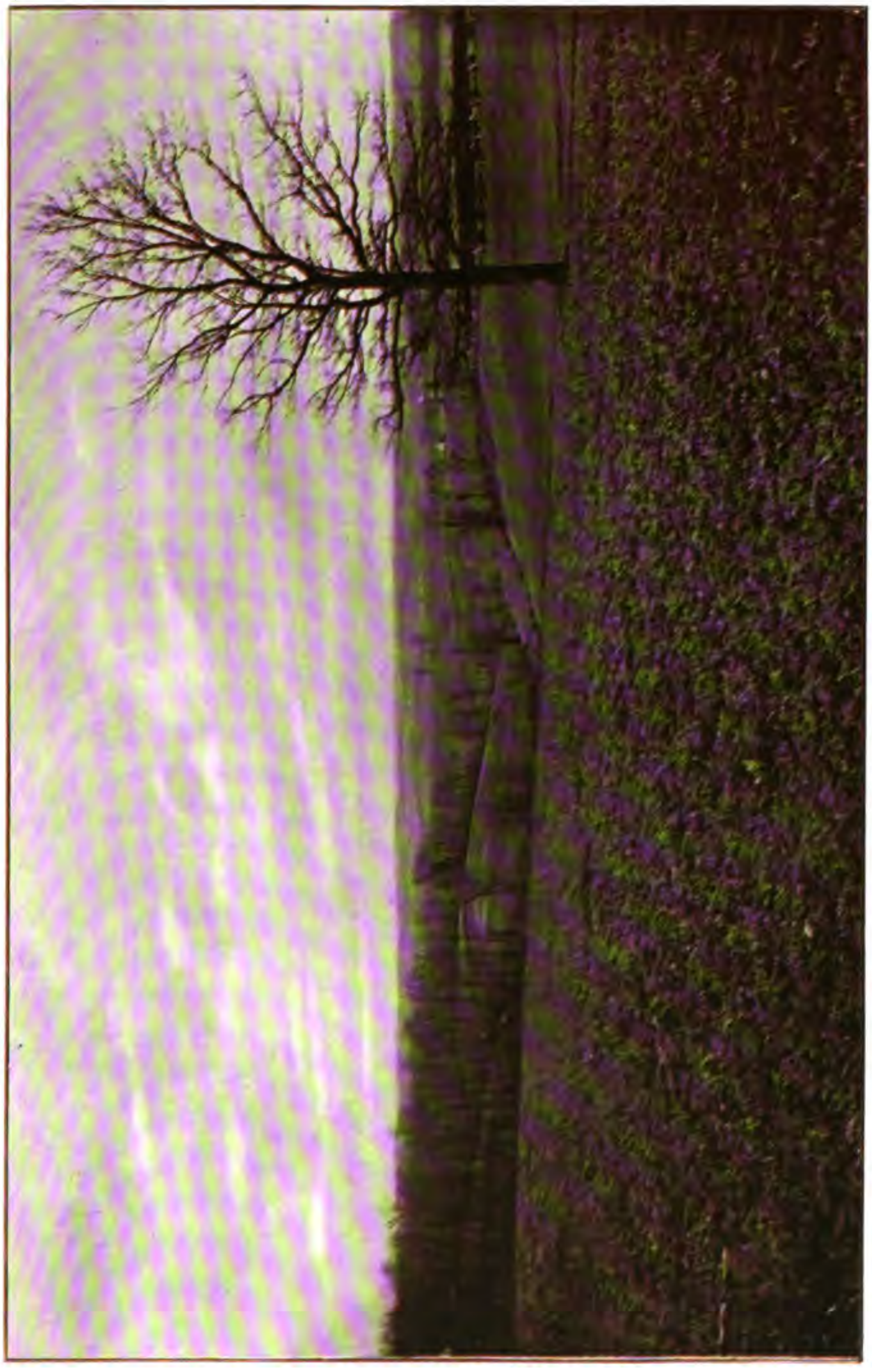
Deer Creek rises in the gneissic areas of the northwestern corner of Harford county, Maryland, and southern York county, Pennsylvania, and drains the whole northwestern portion of Baltimore county. The general direction of the drainage system is southeast as far as The Rocks, where after passing through the gorge at this point the stream changes to an easterly direction and empties into the Susquehanna about eight miles above Havre de Grace. Across its path lie bands of gneiss, phyllite, slates and quartzites, pyroxenite, gabbro, and granite, each having its own characteristic topography.

From its headwaters down to The Rocks, Deer Creek and its tribu-

taries may be regarded as a physiographic unit. This portion of its course lies partly in the gneiss and partly in the phyllite. The foliation and lines of structural weakness of these rocks strike northeast and southwest, while the general trend of the main stream is at right angles to this direction. The stream thus shows disregard for the relatively greater resistance of the silicious bands that are mingled with the much less resistant micaceous facies of the phyllites. All the stream courses are sunk below the general level of a peneplain, whose surface is well preserved in the accordant crests of many hills on either side of Rocky Ridge. The peneplain stands fifty or seventy-five feet below the long even crests of Rocky Ridge and Slate Ridge. It is particularly well developed in the vicinity of Belair, along the course of Deer Creek both above and below The Rocks and along Winter run. The appearance of the peneplain above The Rocks is shown by Plate XVII.

The hill-slopes bounding the valleys of Deer Creek and Little Deer Creek fall rapidly from the gently undulating surface of the Belair peneplain down to the broad flood-plains that characterize even the smaller streams of this system. They are frequently roughened by small ledges whose ragged faces, half-buried by the present flood-plains, show that they once bounded more rugged gorges and valleys.

FLOOD-PLAINS.—The bottom-lands that characterize these streams are clearly shown by two lines of evidence to be flood-plains. Wherever fences cross the bottom-lands they are built in the form of swing gates, such as are used to fence across a stream. This indicates that floods in these valleys are frequently high enough to destroy fragile structures built across them. Again, the structure of the bottom-lands or meadows as exhibited in the banks of the streams during low water points to a constructive rather than a destructive origin. For example, a vertical section of the flood-plain on Little Deer Creek exposed but a few hundred feet above its junction with Big Deer Creek shows at the top one and one-half feet of rich black loam overlying three feet of gravel. The constituents of the gravels have a diameter of about one and one-half inches near the top and increase to boulders of a foot or more at the base. These pebbles and boulders



ROCKY RIDGE AND THE VALLEY OF DEER CREEK.

are water-worn, rounded or subangular fragments of phyllite, quartzite and vein quartz, and have evidently been derived from points near at hand. The width of the meadowland, which continues down stream as far as The Rocks, varies somewhat. It is broadest across the less resistant bands of the phyllite and narrowest in the siliceous and quartzitic areas where it reaches a minimum width of fifty feet. In spite of the fact that the valleys broaden very markedly when on the phyllites and by their narrowing indicate that the quartzites are harder to reduce, yet there is no apparent tendency on the part of the main stream to seek out a more convenient course along the more yielding rocks or to follow the strike of the foliation and jointing planes of either. This applies more particularly to Big Deer Creek, as Little Deer Creek appears to have developed its course more nearly along these lines of least resistance.

Broad Creek.

The headwaters of Broad Creek, that is those west of Pylesville, have developed mild contours over their drainage basin. Standing on the refuse piles of the first slate quarry south of Cambria station one looks westward across fertile, gently rolling fields well watered by streams with broad bottom-lands, all converging towards Pylesville to form the main stream. At Pylesville it has cut its way through the slates, quartzites, and conglomerates of Slate Ridge, thus opening a passage for itself, the railroad and the highway. The creek itself is about six feet wide and as many deep at Pylesville, but after crossing the ridge of slates it opens out in a broad meadow, along one side of which it flows for five or six rods until it enters the gorge through the quartzite. This gorge has a flood-plain forty to eighty feet in width which is strewn with boulders two feet and less in diameter and is evidently submerged during moderate floods, since its present dry portions are much tangled by driftwood. The sides of the gorge rise rapidly, in the lower portion even precipitously, to a height of one hundred feet above the channel and are densely wooded. The stream flows rapidly over gravel shoals and across sharp ledges of micaceous quartzite and conglomerate at the lower end and in no part of the gorge is there even a low cascade. These facts indicate that the stream has nearly established a graded channel.

After flowing for a quarter of a mile through this narrow gorge Broad Creek emerges upon a broad meadow whose even surface stands at a level which is four or five feet above the ordinary level of the stream. This meadow-land, stretching out sometimes to a width of a quarter of a mile, runs squarely against the foot of the steep slopes of rocky cliffs descending to it from the even upland surface. The rocks underlying this meadow are chloritic phyllites that are especially subject to decay and removal wherever they are found in the Piedmont, while the more resistant bands of quartzite and conglomerate serve to retain the prominent benches and form the bare ledges which sometimes bound the meadow-land.

Viewing the topography thus far described it may be briefly summed up as follows: The primary feature of the district is the broad extent of the peneplain extending in all directions as a gently rolling surface. Running northeast and southwest and rising above the general upland are the even-crested elevations of Rocky Ridge and Slate Ridge. Besides these higher elevations there are less prominent inequalities of the surface caused by the resistant bands of the quartzitic gneiss and the serpentine which intersect the general areas of gneiss and granite. The streams pursue general eastward courses whose directions are only very slightly influenced by the variations in the rocks across which they flow. The valleys are sunk below the general upland as relatively wide trenches, except where they cross an unusually resistant band. When within two or three miles of the Susquehanna these streams lose their broad-bottomed valleys and descend to the level of the larger river through steep narrow defiles with their channels frequently broken by low cascades.

James' and Bynum's Runs.

These two short streams have the same general characters and one description will serve for both. Both streams head on the mildly undulating surface of the Piedmont Plateau just south of Deer Creek. The characters of their headwaters are those of a stream on a well reduced land surface. The upper valleys are shallow and broad with very mild slopes from divide to stream channel, and the streams flow quietly through alluvial meadows with very moderate stream grades.

On either side of the turnpike from Belair to Churchville the topography is mild and is easily distinguishable from the rolling slopes descending on the north toward the channel of Deer creek. On the south the topography and character of the streams change rapidly and the broad divide merges into the more cut-up surface of the middle portion of the drainage system. The stream valleys become steeper sided and the washed-in detritus from the slopes forms small alluvial bottoms over which the streams meander during the summer. Where the streams pass the "Fall Line" they become more troubled and flow more rapidly over low cascades which alternate with short stretches of quiet water.

Little Gunpowder Falls.

The Little Gunpowder Falls, which forms the lower portion of the boundary between Harford and Baltimore counties, rises on the phyllites and gneisses between Monkton and Blackhorse and flows in a southeasterly course as far as the estuary of the Gunpowder river, where it enters the waters of Chesapeake Bay. In its course it traverses phyllites, marbles, gneisses, gabbros, and granites without any appreciable conformation to the differences in resistance to erosion which these various rocks present.

The headwaters show that the stream is now increasing its drainage basin, but at a lower rate than the Big Gunpowder. The rocks underlying its upper course are gneisses ranging in character from the weak muscovite gneiss to the less yielding fine-grained hornblende gneisses. Where the stream passes over bands of the latter type the valleys become somewhat contracted and the scenery a little more rugged. Lower down on its course, as near Taylorville, the Little Gunpowder crosses narrow lenses of marble which are more easily corroded than the less calcareous gneisses and schists. Wherever the stream encounters the marble it is customary to find it meandering through broad and fertile meadow-lands which are often flooded after heavy rains. The lower course of the Falls adjacent to the trestle of the Baltimore and Lehigh Railway is in a narrow gorge eighty to one hundred feet below the ordinary level of the upland. The stream channel is filled with angular fragments of gneiss, quartz and

schist, and frequently has low ledges of gneiss cutting across it. The flow is rapid and the stream seems to be working steadily even when the low waters of summer enable it to handle only the coarse sand and finer gravels.

The last phase of the stream's inter-Piedmont course is entered just below the mills at Reckford, where the channel becomes of less uniform grade and is characterized by short stretches which are practically level in times of flood. The alluvial meadows built up of the sands, gravels and alluvium brought down by the floods at high water become broader and the stream flows in a more irregular course with a rapid current.

Big Gunpowder Falls.

The Big Gunpowder rises on the phyllites in the northeast corner of Carroll county, and flows in a general southeasterly direction across the phyllite, gneiss and marble belts of central Baltimore county to the head of the Gunpowder estuary, where both the Big and the Little Gunpowder empty into Chesapeake Bay. The waters forming the lower courses of this river are the combined product of the confluence of three main branches forming the chief drainage lines of northern and central Baltimore county. The more northerly branches unite near Monkton and are known, respectively, as the North, or Main Gunpowder, and the West Branch of the Gunpowder. The usage of these terms is somewhat unfortunate since the more prominent and larger stream is known as the West Branch while the smaller and less important is known as the Big Gunpowder.

THE NORTH OR MAIN BRANCH.—The latter rises just across the Pennsylvania line in south-central York county. As it enters the state it is relatively small, having a width of only six feet, and is only about fifteen feet wide a short distance above its junction with the West Branch near Monkton. Its valley is conformable to the size of the stream and, as far as Monkton, has a rather open character. Near the state boundary the stream flows rather rapidly through a narrow alluvial plain bounded by hills inclined at an angle of about 30° to the flood-plain. The rounded contours indicate only a moderate rate of denudation. The slopes meet the flood-plain in a sharp line and change their inclination to a much flatter angle as the crests

of the hills are approached. Following down the stream the banks continue steep, but the increasing volume of water makes the lateral cutting on the outside of the curves more active, so that the banks are often precipitous on one side and relatively mild on the other. (Illustrations of these stream-cut cliffs are frequent between Bentley Springs and Monkton.) The flood-plain feature continues for some distance and the plain increases in width somewhat out of proportion to the size of the stream, with the result that the channel is now frequently on the opposite side of the valley from the vertical cliffs which the stream cut at an earlier stage of its development. The shallow, open, yet steep-sided, valley, with its alluvium-lined floor, characterizes the stream as far as its junction with the West Branch. The channel is from forty-five to fifty feet below the hilltops and from fifteen to fifty feet wide, according to the varying resistance of the gneiss. The bed of the stream is made of angular boulders with frequent ledges in the lower part of its course except where covered with sand, gravel and loam.

The side streams flowing into this portion of the Big Gunpowder Falls have their lower courses more or less flood-plained, while in their upper portions, particularly about their incipience, they are marked by steep-sided valleys that sink sharply below the general upland. Generally these streams, after flowing for a longer or shorter distance across broad, flat meadows, enter the Falls without any marked change in their grade. Such is the manner in which Owl Branch, a tributary at Turner's Crossing, and several other streams join the Falls. At Parkton, however, Fourth Mine Run is interrupted by a series of low rapids after leaving its meadow-land. These rapids are due in part to gravel-bars, and in part to ledges of the gneiss that enable Fourth Mine Run to descend about six feet in the course of the hundred yards between its flood-plain and the channel of the Falls. This seems to be an exceptional manner of junction and is probably due to the local development of a more resistant band in the gneiss at this point.

The West Branch.—The larger, more interesting, and more important branch of the Gunpowder, termed the West Branch, results

from the confluence of two streams near the paper-mills southwest of Lineboro, on the Western Maryland Railroad, in the northeastern corner of Carroll county. While local opinion regards the northern branch as more important and as the head of the Gunpowder, near Melrose postoffice, there are just as good reasons for regarding the southern branch, heading north of Manchester, as of equal importance. Both of these streams flow northeast for two or three miles in narrow valleys, then unite and pursue a general southeasterly course for fifteen miles or more across the gneiss and phyllite to a point between Monkton and Whitehall, where the West Branch joins the main stream just described. In this distance it receives the waters of several large tributaries, especially Big Grave Run and Georges Run. The valleys of the two head-streams are characteristic. The northernmost, after emerging from the hills as several small rivulets, flows for some distance through a broad and open limestone valley until just before its union with the Southern Branch when it cuts directly across a band of gneiss forming a steep-sided gorge. This gorge is now filled with an artificial flood-plain, due to the construction of a mill-dam at its lower end. Since the difference in elevation between the northern and southern streams is fully twelve feet, the waters of the stream must have flowed very rapidly through the gorge before they were artificially restricted. The Southern Branch flows in steeper-sloped valleys whose cross-sections approach more closely to the shape of a V. The channels are always marked by narrow flood-plains, which vary in their width according to the character of the underlying rocks. The floor of the valley seems in many instances to be due to the solvent action of the stream and the slowly moving ground-water of the adjacent hills. The stream itself meanders over this plain in a trench, four or five feet below the surface of the valley-floor, exposing a section through alluvium, loam and stream gravels. The presence of angular blocks of gneiss, one or two feet in diameter, in the bed of the stream indicate its *efficiency* during floods.

Below the confluence of the two tributaries the waters flow through broad, level meadows, averaging seventy-five to one hundred feet in width, that make a sharp line at the base of the steeply inclined sides

of the deepening gorge which widens into more gently rounded valleys where the course of the stream is over the less resistant marbles and phyllites. For example, just below Rockdale the West Branch leaves its steep, narrow gorge for half a mile or more and wanders across level meadows a quarter of a mile in width.

At the confluence of the West Branch and its tributaries the valleys usually open out somewhat, and the flood-plain extends up the valleys of its tributaries for a distance of several hundred yards. Above this flood-plain the side streams, such as Georges Run, emerge from small gorges of steep grade which they have cut through the underlying gneiss. Above these smaller gorges the streams are usually in long, broad meadows, extending back to the hills that rise to the general level of the upland.

THE BIG GUNPOWDER.—After the West Branch joins the so-called Falls of the Gunpowder the volume of the Falls is considerably increased and consequently the gorge becomes wider. The increased power resulting from increased volume is indicated by the larger rock fragments now found in its channel and also by the occasional evidences of lateral swing and corrasion found in the flood-plain. Gneiss boulders, two feet in diameter, are found in the channel of the West Branch, while in the flood-plain deposits and in the present channel of the Falls, just below Monkton, a few sub-angular fragments, two to three feet square, occur. A well-marked instance of lateral corrasion, due to increased power, is between Monkton and Pleasant Valley Station. At this point a low level-topped ridge of gneiss rises five feet above the swampy flood-plain. The ridge is almost wholly surrounded by water, even when the Falls are at a low stage, but a low neck of gneiss, about three feet above water level, joins it to the high projecting bank around whose base the Northern Central Railway passes by a cutting and an embankment.

The general characters of the gorge of the Big Gunpowder below Monkton are but slightly modified from those of the gorge above the junction with the West Branch. The flood-plain is on the whole but little wider, averaging sixty or seventy feet, and often narrows to less than fifty feet. It is always a collection of sand and fine gravel,

sometimes with a foot of brown loam on its surface. It abuts sharply against the sides of the gorge, and these are either rocky cliffs or steep grass-grown slopes in which the rocky ledges are but thinly buried. These steep slopes and low cliffs rise sharply for one hundred and fifty or two hundred feet and then round off, grading somewhat less rapidly into the gentle streamward slopes of the general upland. These general features characterize the Big Gunpowder as long as its course lies within an area of gneiss or granite. The bands of marble which it crosses, however, sometimes modify the stream topography in minor details.

After receiving the waters of its largest tributary, Western Run, the Gunpowder passes through one of the most interesting portions of its course, in the vicinity of Cockeysville. While running on the marble, which extends from Ashland to Lutherville and thence eastward to Loch Raven, the stream turns sharply to the east and enters a deep, narrow gorge cut through a boss of granite, which rises three hundred and sixty feet above the level of the marble valley. The stream has scarcely any flood-plain, and at times the gorge becomes so constricted that there has not been room enough to make a road along the edge of the flood-plain without considerable blasting. The bottom-land in this portion of its course, unlike that farther up-stream, has been formed by the abrasive action of the stream on the hard underlying rocks instead of being built up by deposition. Although marble bands are encountered in the passage through this granitic area the level of the marble slopes is little below the general level of the upland surface. There is, however, a bench three hundred and fifty or four hundred feet above the course of the Gunpowder which conforms in altitude to the level of the residual portions of a pre-Potomac valley-floor that has been partially preserved in the Potomac-capped levels at Lutherville, Timonium, and points in the Green Spring Valley.

The lower portion of this gorge, which debouches at Loch Raven, has been modified by the artificial restrictions which have been constructed at the latter point, as a portion of the Baltimore water-supply system. Below the dam the stream enters the continuation of the

marble belt which it left at Ashland, and continues in it until it enters the gneiss once more near Summerfield. Below this point the river flows in a gorge of increased depth and steeper sides, and the rocky channel of the river occupies a narrow trench two hundred and fifty feet below the upland, with a floor varying in width from seventy-five to one hundred feet. The narrow flood-plain extends about twenty-five feet back to the foot of the canyon walls on either side of the stream. Through it project numerous ledges, showing that there is but a thin veneer of alluvium covering the solid gneiss beneath.

The grade of the channel steepens more rapidly from the point two miles above the crossing of the Belair Turnpike to the mouth of the river, and is frequently broken by ledges and small cascades (Plate XIX). As the channel steepens the slopes of the gorge begin to retreat and to lose a little of their steepness, until after a rapid fall and several sharper cascades and rapids the river debouches into its estuary between Loreley and Bradshaw.

Western Run.

Western Run, which is the most important branch of the Gunpowder below Monkton, heads on the limestones and gneisses of Worthington's Valley, just north and east of Glyndon. After flowing across a small tongue of gneiss it runs eastward for about five miles, following the southern boundary between the gneiss and the marble band extending from Glyndon to Glencoe. Two miles west of Belfast P. O. the Run turns sharply southward, deserting the band of marble, and flows for four miles in a winding gorge through the gneiss until it emerges on the marble near Cockeysville, only to re-enter the granite at Ashland Furnace on its way to join the Big Gunpowder Falls, one mile above the Warren cotton-mills. The principal tributaries of this trunk stream from west to east are Gladman's Run on the south, Piney Run and Black Rock Run on the north, and Beaver Dam Creek which enters it from the southwest.

Much of the territory drained by these streams is characterized by broad, open, slightly rolling valleys of very moderate depth, bounded by rather steep slopes. The trend and boundaries of these valleys are

intimately related, in most instances, to the direction and extent of the marble areas that occur as a number of narrow, approximately parallel bands, separated by narrow strips of gneiss. The drainage lines, as shown by the large scale map (Plate XVI), run directly across the general trend of the bands, and with the exception of the northern branch of Beaver Dam Creek, only small streams have courses along the marble. The general level of the area formed of these interwoven bands of marble and gneiss, is slightly below that of the surrounding rocks. The gneiss bands usually form the minor divides within the basin, but not infrequently the divides run as easily across the marble as across the gneiss. The two broader areas of marble occurring at Belfast P. O. and Mantua Mills, where the narrow bands unite, are lower than the general level of the area because of the greater solution to which they have been subjected, owing to the fact that both of them are crossed by moderate-sized runs.

FIG. 16.—Profile across Western Run Valley.

The vicinity of Belfast P. O. and Priceville now appears as a plain, whose trenched and slightly dissected surface is indicated by the summits of gently rolling hills bounded by comparatively steep slopes of gneiss. The summits representing the former valley-floor are now covered with a thin deposit of coarse gravel and cobbles of vein quartz that have been brought from some distance and deposited by a stream larger than the Piney Run of to-day.

PINEY RUN.—Piney Run and its tributary, McGill's Run, rise on the gneiss of Baltimore county near the Carroll county line, due east of Westminster. The two streams follow parallel courses across gneiss, phyllite, and marble down to Dover, where they unite and flow by a common channel to Western Run. These streams have sharply incised and steeply bounded courses on the gneiss, with fresh flood-plains of moderate width, and channels which are largely composed of gneiss fragments and, rarely, quartz pebbles.

GLADMAN'S RUN.—Just at Mantua Mills, half a mile below the

mouth of Piney Run, Gladman's Run joins Western Run. This tributary rises on the large gneiss area west of Cockeysville and flows northward across the narrow marble and gneiss belts to the main stream. The hills gather closely about its headwaters on the gneiss and rise steeply from the stream-bed, but in the marble they become lower and more rounded towards the stream, while a flood-plain thirty feet wide is developed and continues with the stream until it emerges into the flood-plain of Western Run. Small subsequent valleys are being developed on the narrow marble band, but they are clearly in very youthful stages of development. Gladman's Run, in crossing the narrow band of gneiss south of Western Run Valley, does not seem to suffer any contraction in the width of its channel. The Run is here about six feet wide and flows in a meandering course on a flood-plain fifty feet wide. Its channel is chiefly of gravels and sand. The gneiss hills are generally more or less under cultivation and slope down sharply for about thirty-five feet to the level flood-plain of the Run.

Black Rock Run.—Black Rock Run, like Piney Run, rises on the gneiss and phyllite areas northwest of the marble bands and flows southeast across the marble bands and gneiss to join Western Run near the crossing of the Falls Turnpike. In its upper course it is a small and rapid stream, three to six feet wide, flowing through a broad, level meadow-land. The flood-plain has a width of about two hundred feet on the main branch and is bounded by steep, smoothly rounded slopes of chloritic schist. A smaller tributary, flowing parallel to this portion of the main stream and lying west of it, has a very similar valley though on a smaller scale. The steep side-slopes, however, are in this latter instance less rounded and more rugged and along the lower portion of the stream course they are sometimes even precipitous.

About seven miles from its headwaters Black Rock Run crosses a narrow band of marble, at the same time turning southwest and following the southern edge of the marble for about a mile before it bends southward and again cuts into the gneiss. Just where it makes the first bend after entering its valley on the marble, a small subse-

quent, also located on the marble, joins the Run from the east. This small stream is bounded by steep slopes of the marble, and its head-divide on the latter is still almost as high as the general level of the gneiss-supported upland. As the junction with the larger stream is approached this narrow valley widens, the contours become milder and the general characters of a valley developed upon a marble or limestone band appear.

In this small subsequent valley, known as Stringtown Valley, better than at any other locality in the Piedmont province, is seen the influence exerted by structure on the marble valleys of the district. The foliation-planes of the gneiss and phyllite and the associated beds of marble and quartzite all have a general southeast dip with an inclination of about 30°. The planes of weakness and fracture of the marble are parallel to the planes of foliation. Therefore, a stream working out its channel on the marble would have a tendency to shift its channel laterally down the dip, because solution would be easier and more rapid on that side of the stream. This shifting would also be aided by the ease with which undermining of the opposite bank by lateral corrasion could be carried on (see Fig. 5). Now, the right or northwest valley-slope of Black Rock Run has a very mild and even descent to the flood-plain of the stream, while the left hand or southeast slope is steep and rough with the stream flowing at or near the base. The right hand slope is largely on the marble, while the left hand slope is about two-thirds on the gneiss. Thus the configuration of the valley is not symmetrical with respect to the location of the stream as is the usual case, but has a cross-section resembling L with the stream at the lowest point. These unequal slopes pass down into the even levels of the flood-plain and meadow-lands through which Black Rock Run meanders for half a mile to its confluence with the smaller western branch.

At the junction of the two streams the course turns southward into the gneiss and enters a wild, narrow gorge just above Butler P. O. This gorge is half a mile long, scarcely two hundred feet wide, and its steep, rugged slopes are often bare, rocky ledges which stand out as ribs of gneiss or quartzite. The cliffs slope abruptly down two

hundred feet to the rocky channel of the stream. About a quarter of a mile from the head of the gorge there is a band of resistant quartzite which has withstood the wearing of the stream so well that a waterfall thirty feet in height still bears witness to the hardness of the ledge, although the channel has now cut down one hundred or one hundred and fifty feet below the top of the gorge. This ledge has been utilized as the foundation of a mill-dam which still ponds the stream above the falls, though the mill which it once supplied with water-power has now fallen to pieces. Above the falls the stream is quiet and inactive, but below the dam there is a rapid current in a channel of steeper grade. It should be observed that the level, down to which Black Rock Run has and can reduce the upper portions of its channel and valley, is determined by the depth to which it can cut this resistant quartzite band in the gneiss. In other words, the level flood-plains and the floor of Stringtown Valley are incipient local peneplains controlled by the quartzite sill. The lower portion of the channel is filled with large and small fragments of quartzitic rocks which bear witness to the great transporting power of the stream at high water. Leaving this narrow course on the broader band of gneiss, the Run occupies a steep-sided but more open course on the narrow marble band just above Butler P. O. There the stream begins to develop a small flood-plain which continues across the gneiss at Butler and widens perceptibly where it joins the meadows along Western Run.

Beaver Dam Creek.—The headwaters of Beaver Dam Creek have their beginning about in the centre of the large gneissic area lying west of the Cockeysville marble quarries and north of the Green Spring Valley. The stream occupies a rather shallow, open valley on the gneiss uplands and descends through a steep, narrow, wooded ravine with very steep grades to emerge from this shut-in portion of its course near the marble quarries at Cockeysville. Thence it follows a northeasterly course across a broad rolling valley of marble, two miles in width, until at Ashland a sudden turn to the east carries the Creek against the gneiss hills overlooking Cockeysville on the east. Through these high hills it has cut a gorge a mile in length, three hundred feet deep and fifty feet in width in its course to the Gunpowder.

A large branch of Beaver Dam Creek drains the eastern half of a narrow marble band and valley lying north of the gneiss on which Beaver Dam Creek heads, and joins the Creek on the north, midway between Cockeysville and the quarries. Thus its whole course lies on the marble. The headwaters of this branch have worked back westward along the marble about as far as the headwaters of Beaver Dam Creek, but the side branching of the latter stream is much more intricate than that of the former. Small side-streams of this northern branch have cut relatively short steep-sided ravines in the gneiss slope on either side the marble, but they are very limited in their extent and are as yet mere tendrils reaching out only a short distance from the main stem. This branch of Beaver Dam Creek (incorrectly designated as Western Run on the Baltimore sheet of the U. S. Geological Survey) has its narrow valley partially filled with iron-ore bearing sands and clays, which are similar to and evidently of the same age as those found in the Green Spring Valley and in the vicinity of Lutherville. These deposits are mainly confined to the southern flank of the valley and extend half way up to the top of the gneiss hills. Besides these terrace-like deposits about Oregon the smooth floor and gentle, even slopes of this valley are sparsely strewn with gravel and small cobbles of not more than five inches diameter. The valley thus simulates in every way, except in size, the even-floored, gravel-strewn Green Spring Valley, and the same kind of evidence points to its having had the same origin and history.

Jones' Falls.

Jones' Falls, like Western Run, drains a valley located along a marble band, the Green Spring Valley, and so far appears to have taken advantage of the opportunities offered by calcareous rocks for developing a drainage basin with the smallest possible expenditure of energy. It also takes an anomalous course across a point of comparatively unyielding gneiss when it might have followed an easier course around the point, by keeping to the marble. These two contradictory performances by the stream, as well as the considerable amount of interest that many of the inhabitants of Baltimore are forced to take in the stream, are sufficient to draw attention to it.

Jones' Falls may be said to originate on the gneiss northwest of the small oval marble area called "The Caves." Three quite minutely branching streamlets flow from the gneiss into the basin-like depression of "The Caves," and there uniting in one stream, pass out through a deep, rugged defile leading from its southeastern corner. The stream continues in a steeply bounded course until it reaches the Green Spring Valley, west of Chattolanee and opposite the station of Stevenson on the Green Spring Valley branch of the Northern Central Railway. Here it is joined by the somewhat smaller stream that has pushed its head along the Green Spring marble out to Reisterstown Turnpike. The principal fork of this small tributary heads on the gneiss northeast of Chattolanee Hotel and flows south, while a small run flowing north from the same point drains the southwest corner of "The Caves." The crest of the divide between these two small runs is relatively wide and below the general elevation of neighboring stream-divides. The crest of this low, saddle-shaped divide stands at five hundred and forty feet above the level of the sea, while the altitude of divides between much larger streams in the immediate neighborhood averages at least six hundred feet, and the general altitude of the rolling upland plateau is six hundred and fifty feet.

It is a noteworthy fact that all the streams joining Jones' Falls from the south are small and insignificant in volume, though two branches of good size unite with the main stream on the west of Rockland and the large West Branch at Mt. Washington brings a considerable volume of water to swell the stream. This characteristic of shortened affluents from the south may also be observed in the case of Mine Bank Run and its fellow of the Gunpowder drainage west of Loch Raven station, and to an equally marked degree in the case of Western Run. Such unsymmetrical drainage patterns, departing so widely from the normal plan, which is beautifully exhibited over neighboring portions of the Piedmont Plateau, indicates that some disturbing factor is, or has been, acting to cause these variations. It is true that along the south side of the Green Spring and Mine Bank Run valleys there is developed a heavy quartzitic

phase of the general gneisses which is lacking on the north boundary, and it is natural at first to conclude that the stunted growth of the streams entering from the south is the result of the superior resistance offered by this quartzite band. This is undoubtedly an important factor and it must be conceded that, in part at least, the slight development of these streams may thus be accounted for. When, however, the two sets of tributaries which supply Western Run are compared in a similar way it appears that here also there exists a greater development of the northern tributaries. The lithologic conditions in the two cases are often precisely the reverse. No resistant band of quartzite runs along the southern boundary of the main valley. On the contrary, the quartzite, which is frequently associated with the Piedmont marble bands, has been found chiefly, if not solely developed along the northern boundaries of Western Run Valley. Indeed, it is a significant fact that in the cases of Black Rock Run and others, the streams have cut gorges through beds of quartzites and yet exhibit a greater headwater development than the smaller tributaries of Jones' Falls.

These facts make it impossible to explain the development of the streams by regarding them as merely the products of the usual shifting of divides controlled by the lithological variations in the territory drained.

Two explanations for this unsymmetrical development of tributaries may be offered. The first is that a general tilting of the land toward the south has increased the activity of the southward-flowing streams, while it has put the northward-flowing streams at a disadvantage. The second explanation assumes that originally the general trend of the whole drainage was continuously southeastward, but that certain streams, favored by being originally located on the less resistant marble, have subsequently developed rapidly along these lines of least resistance, have intercepted and diverted the southeastward drainage lines and, deepening their valleys, have developed short, young side-streams from the south while keeping the long, old tributaries from the north.

Proceeding according to the first hypothesis, suppose that Fig. 17

represents the cross-section or cross-profile of a valley and its side slopes, drawn to natural scale. The main stream at ordinary stage wanders somewhat from side to side of its valley V building a narrow flood-plain. It is supplied by side-streams which drain the general surface of the upland $R - P$, and may be assumed to be equally developed on either side. As long as the land remains in this attitude erosion and stream development will proceed evenly and no peculiar features will be developed which cannot be referred to the usual processes of stream evolution upon a terrane of varying lithologic character. There will be a rapid development by the streams of a grade that will represent a balance between the volume, the load and the declivity of grade of the stream. The grade thus established will be maintained as long as the factors which have determined it remain constant. If from any cause this condition of affairs is altered by a tilting to the left the balance of forces before obtaining

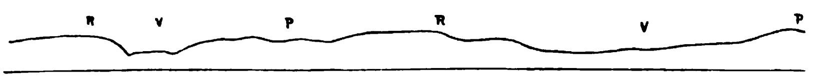


FIG. 17.

will be disturbed and changes in stream activities must result. The immediate effect of such a tilt is to alter the slopes of the beds of those streams whose directions were more or less at right angles to the axis of tilting. A little study of the figure will make it plain that such a change in the general attitude of the land will decrease the steepness of the slope from R to V, while the valley-slope from P to V will have increased declivity. Moreover, since the valley-bottom V has an appreciable breadth it also will undergo tilting towards R, and the effect will be a shifting of the stream towards the latter point. The streams whose courses lie from P to V, having their beds steepened, would experience an increase in the velocity of their currents, a corresponding increase in cutting power, and a consequently increased rate in the deepening of the channels and in the extension of the headwaters. On the other hand, the streams flowing from R to V would experience a decrease in their slope and a consequent loss in their velocity and cutting power.

They would accordingly not be able to extend their drainage areas as rapidly as before, or to deepen their channels. If sufficient time elapses it must come to pass that streams on the slope $P — V$ will extend their headwaters at the expense of streams on the slope $R — V$, thus shortening the latter streams.

In an area which has been tilted, therefore, the streams flowing in the direction of the tilting will have deeper valleys, more rapid currents, and an increased branching among their headwaters. The streams flowing against the tilt, on the other hand, may be of the same depth as before the tilting, or possibly even less, since the decreased velocity of the streams may cause them to deposit some of their load of debris. They may not extend their drainage basins by headwater erosion and may even suffer some shrinkage in volume as the result of the encroachment of the other more favored streams.

A comparison of the conditions demanded by the preceding explanation with those obtaining in the main streams and tributaries of Jones' Falls and Western Run shows that while there are many points in common the degree of coincidence is not marked. Although the streams flowing southward uniformly have greater development and are more aggressive and powerful than those flowing northward, and although the streams flowing eastward follow the south side of their valleys more or less closely, yet those flowing northward are rarely one-half as long or one-third as well supplied with smaller side-streams as those from the north. The former, moreover, do not show any sign of decreasing in volume or lessening of grade, but, on the contrary, present the steeply bounded, narrow valleys with high-grade channels that characterize side-streams in their earlier stages of development. It is, therefore, evident that the preceding hypothesis of a general tilting does not fully explain the unsymmetrical distribution of the tributaries.

The second hypothesis, based upon a partial rearrangement of the drainage lines of the two streams from a former, more southerly course, requires at the outset some competent means of placing the large and small streams in their initial positions across the marble and quartzite beds. This may be accomplished by supposing the whole

network of drainage lines newly located upon the face of the country across gneiss, quartzite, marble, or serpentine without reference to any differences in resistance.

Starting with an initial arrangement of the drainage somewhat as shown by the accompanying diagram, Fig. 18, the history of the stream may be inferred as follows: As the various streams cut their channels deeper and gradually pushed out their headwater and side-streams, the branches already located on the marble and the new tributaries there originating were able to grow in size and power more rapidly than the streams located on the resistant gneiss and

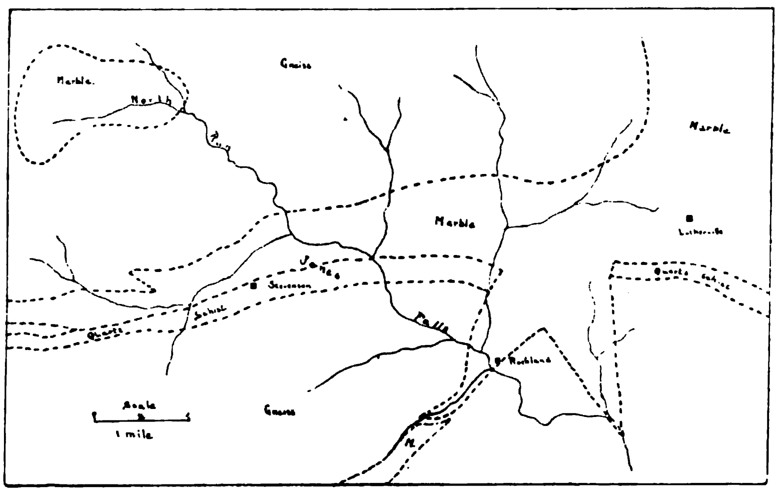


FIG. 18.—Former unadjusted course of Jones' Falls.

quartzite. These favorably located streams thus outstripping in their growth the others and guided in their development by the course of the marble bands would soon cause some readjustment of the smaller streams. For example, a small side-stream beginning near Rockland may have worked northward past the quartzite ridge and acquired headwaters from the north and side-streams on the marble.[1] Starting

[1] This is a very probable change, for a stream flowing across the point of gneiss with its hard, resistant quartzite facing, would need a very long time to reduce its channel, while a much smaller stream starting on the soluble marble would wear down its course very rapidly.

from the same point, Rockland, the smaller stream would then reduce its channel to a lower grade than the slightly larger stream on the gneiss could possibly do in the same time. Soon a critical stage in the position of the divide between the two streams would be reached. The smaller stream, from its lower grade, could push its divide nearer and nearer to the main channel of the larger and higher stream, until at last the latter would be intersected and all the waters of its upper course be diverted into the channel of the small invading

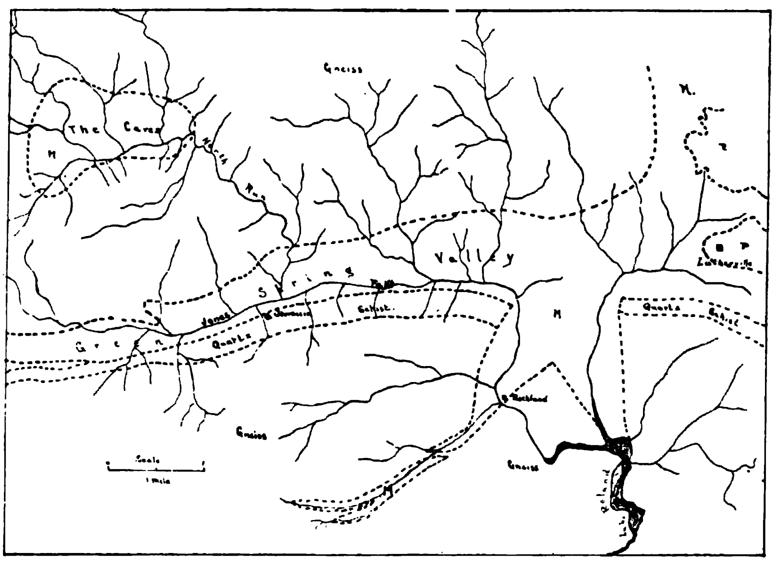


FIG. 19.—Present partially adjusted course of Jones' Falls.

diverter. The lower course of the beheaded stream would continue in its former channel but much shrunken in volume and unable to push its headwaters against the opposition of the more powerful and favored pirate stream that cut off its headwaters. The same or closely similar changes would be going on between the other streams where they cross the marble belt. Various interstream adjustments probably would occur until, finally, Jones' Falls, as at present, favored by the long stretch of marble down to Lake Roland and Rockland, had captured the heads of all the streams crossing the eastern portion

of the marble, and led out the drainage by one common channel around the gneiss and down to Rockland.

While these changes in the stream courses were slowly being accomplished the streams must have been gradually deepening their channels in the gneiss until one by one they were diverted to courses on the marble. If this is the manner in which the Jones' Falls and Western Run systems were developed, there should be some traces of the valleys carved by the streams before their diversion. Since no such abandoned channels have been found, it must be inferred either that the diversion of the earlier stream courses proceeded so rapidly that the courses on the gneiss were not deepened sufficiently to permit of their being distinguished amidst the various inequalities now existing, or that the early streams were not originally placed as supposed but were gathered into common channels along Green Spring Valley and Western Run.

A third hypothesis assumes that the sediments of the Coastal Plain were formerly thick enough in this area to completely mask the former Piedmont topography, and that the streams were located independently of earlier valleys and divides and were controlled only by the surface configurations of the Coastal Plain.

No one of these various hypotheses is entirely satisfactory and the facts at hand seem to indicate that this unsymmetrical distribution of the tributaries is not due to a simple cause but is the result of the combined action of two or more such sets of conditions as have been implied in the foregoing hypotheses.

Age of Jones' Falls.—At several points along the lower course of Jones' Falls, especially within the corporate limits of Baltimore city, are beds of coarse gravel, sands, and clays, resting on the beveled edges of the gabbro and gneiss. The line of contact between these two formations is well shown near the eastern end of North avenue bridge and at the Jones' Falls gneiss quarries some distance up-stream. At both exposures the contact appears as a sharply drawn horizontal line separating the even, flat surface of the eroded crystallines from the heavy deposits of gravel which have been determined by Darton [1] as of

[1] See "Geological Map of Baltimore and Vicinity," Geo. H. Williams, Ed.; pub. by Johns Hopkins University, 1892. N. H. Darton on Sedimentary Formations.

Pleistocene age. Similar gravels are found scattered over the limestone floor of the Green Spring Valley. At a point opposite Stevenson fifty or sixty feet above the present stream channel are located some old abandoned iron mines. The exposures in the open pit show the following section of sedimentary deposit. At the bottom are about fifteen feet of stratified mottled red and white clays with several beds of fine, white quartz sand and clayey pellets. Above the sand and clay pellet bed come two or three feet of gravel in which the diameter of the pebbles does not average above three or four inches. The pebbles are of quartz and well rounded, and may therefore be set down either as of marine littoral or of fluviatile origin. These characteristics ally the deposits with those of the Potomac[1] group, and this correlation is corroborated by the fact that neighboring portions of this same marble tract are overlaid by Potomac beds. It is therefore evident that the depression now called Green Spring Valley and occupied by the headwaters of Jones' Falls was in existence as a depression in Potomac time, and that it was submerged during the same period and received the deposits above mentioned. Later, the Pleistocene gravels were spread over the eroded surface of these earlier formations and through these clays, gravels and crystallines the present Falls has cut and is still cutting its lower gorge. The stream at this point must, therefore, be younger than the Pleistocene deposits below which it has trenched its channel.

Discussion of Profile.—The accompanying line drawing, Plate XIX, represents in some detail the varying slope or grade of Jones' Falls channel, and a study of this profile brings out several interesting facts concerning the development of the stream. The first obvious fact is that the bed of the stream, where located on rocks, approximately uniform in lithologic character, has well-defined and widely recognized features. Starting from the divide the grade is at first very steep but rapidly loses its declivity, and for two-thirds of its length approaches the horizontal by constantly decreasing amounts. The normal grade is shown by the dotted line below the solid one representing the profile of Jones' Falls. While the upper half of the Jones' Falls curve is substantially in accord with the normal profile,

[1] Report of Maryland Geological Survey, vol. i, 1897, p. 190.

the lower half of its course deviates very markedly from the latter curve. Instead of being slightly concave and very nearly horizontal the channel descends by a decidedly convex curve. Thus the upper half of the stream is characterized by a matured and perfected grade profile, while its lower course has a very youthful character.

Besides this marked change in the general form of the stream's grade between Green Spring Valley and Baltimore, there are several smaller cases of sudden change of grade extending over shorter stretches. The best-defined localities, where these breaks in the even continuity of the grade occur, as shown by the drawing, are at and just below the dam at Lake Roland, at Woodberry and Hampden, opposite Druid Hill Park, and in Baltimore between Eager and Preston streets. At each of these points the stream drops from ten to twenty feet by low falls or cascades within stretches of fifty yards or less. An exception is found at Woodberry where, in the course of half a mile, the stream falls forty feet. These several interruptions in the evenly descending profile of the stream might be due to one of two causes, both of which are to be found within the Piedmont Plateau province. A band of rock more resistant than adjacent rocks down-stream will produce such falls, because it will persist as more or less of an obstruction to the stream after the more easily removed bands down-stream have been worn down to a lower level and a milder slope. Falls due to such obstructions are especially common in the Appalachian region where the mountains and ridges are composed of strata of different degrees of resistance. A more closely allied illustration is found at the rocks of Deer Creek where quartzite and conglomerate produce a cascade in Deer Creek because they are more resistant than the foliated micaceous gneiss farther down-stream.

The second cause for such cascades is dislocation. If a plane of dislocation or faulting with the up-throw on the up-stream side, or the down-throw on the down-stream side, cross the channel of a stream, then, supposing any considerable dislocation to have taken place along that plane since the stream began to cut its channel, it is plain that there must be some cascade or fall in the stream from

the uplifted side to the down-thrown side of the plane. McGee[1] has explained the cascades on the eastward-flowing Piedmont streams by assuming both causes. In the particular case of Jones' Falls, and also on one or two other streams, it is found that most of the cascades and falls occur where dikes of medium-grained pegmatite have been intruded in the gneiss. This pegmatite is less easily corraded than the foliated, micaceous gneiss, and therefore stands out in slight relief on the steam-bed as the sill of the falls. There are no evidences of special faulting in the immediate vicinity of the cascades except in the drop just below Lake Roland; but as there are undoubtedly numerous small faults throughout the Piedmont, it is possible, perhaps probable, that these fall-points are located by such dislocations as well as by the more resistant pegmatite.

The recent elevation of the stream basin, inferred from the trenching of the Jones' Falls channel below the Pleistocene gravels, is verified by the character of the stream's profile. The concave profile of the up-stream area contrasted with the convex profile lower down clearly indicates that, after once having reduced its channel to a normal profile (Fig. 3) and having had the Pleistocene gravels and clays spread along it, a subsequent uplift has incited the stream to renewed activity in cutting its channel to the new and lower base-level. When a stream thus begins to reduce its channel to a new level the start is made at the lowest point, or the mouth of the stream, and thence the work of reduction proceeds backwards up-stream. The profile suggests that the Falls is already approaching its new grade along that portion of its course between North avenue and the harbor, but the convexity of the profile between Baltimore and Lake Roland indicates that along that portion of its course the down-cutting of the stream is still insufficient to counteract the upward tendency of the land. The profile of the Falls in Pleistocene times, as evidenced by the levels of the remaining gravels, is represented by the dot and dash line of the drawing.

[1] W J McGee, U. S. Geol. Surv. 8th Ann. Rept., 1885-6, p. 620, etc., and plate lxviii.

THE HELIOTYPE PRINTING CO. BOSTON

PATAPSCO VALLEY, FROM WOODSTOCK COLLEGE.

ON THE BALTIMORE & OHIO RAILROAD.

Patapsco River.

The drainage basin of the Patapsco may be divided into two subdivisions of unequal size and power, corresponding to the two main branches of the river. The larger stream, or the North Branch, which has its headwaters on the eastern slope of Parr's Ridge in the vicinity of Westminster, flows southeastward about ten miles to the Baltimore county line, near Glen Falls, and then turns southward following a somewhat tortuous course to its junction with the South Branch between Marriottsville and Woodstock. The smaller, South Branch, also rises on Parr's Ridge, about sixteen miles south of Westminster, in the immediate vicinity of Mount Airy, and pursues a winding course whose general direction is due east for about sixteen miles before it unites with the North Branch to form the main stem of the Patapsco. From this confluence the Patapsco pursues a broadly curving course, turning finally southeastward and eastward to enter the head of the Patapsco estuary, twenty miles from Marriottsville.

South Branch.—The South Branch occupies a shallow, meandering gorge depressed about two hundred feet below the general level of the Piedmont upland. The valley of the stream in its upper portion has few canyon-like characters, but is comparatively broad and shallow on account of the somewhat less resistant nature of the rocks in this district. Small lenses or bands of rock of greater resistance cross the valley, for example, at Woodbine Station or on the railroad between Hood's Mills and Morgan, causing the bounding slopes to increase in declivity and the valley to become slightly narrower. A short distance above Sykesville the valley begins to lose the more open character of its upper portion and gradually narrows and steepens, its side-slopes assuming the more gorge-like characters which it retains with minor variations down to its junction with the North Branch.

The particular bands of resistant gneiss mentioned above have special interest because of the marked influence which they have exerted on *the development of the flood-plains* of the stream and on the past industries of the locality. By reason of the resistance which

these bands offer to the down-cutting of the channel, small side-streams flowing into the South Branch above them have, with the aid of the larger stream, developed marked expansions of the valley and the flood-plain. The resistant ledges produce low falls in the main channel and have furnished favorable sites for two mill-dams. The quiet waters of the ponds produced by these dams were favorable to the deposition of considerable quantities of mud which have partly obscured the surface of the eroded expansions of the valley. Now that the dams are broken the ponds are drained and their old bottoms have become green swamp- and bog-lands, resembling the poorly drained surface of a glaciated district, or the former channel of a beheaded stream.

The flood-plain, which is so extensive in the upper portion of the stream, gradually contracts down-stream until it reaches the more confined gorge portion, where it attains a fairly uniform width of two hundred feet. The channel itself is often located on ledges of the metamorphic rocks only thinly covered by beds of gravel and sand, and is sometimes broken in its descent by bare ledges of the rocks appearing through the flood-plain deposits.

All of the more important side-streams of the South Branch, such as Gillis Falls, Piney Run, Piney Branch, and Winter Run, are situated on the northern side of the main stream. As they differ in many respects from the larger stream they deserve especial mention. Their courses may be divided into three portions. The lower parts of the streams are generally occupied for two hundred yards or more by extensions of the flood-plain which bounds the channel of the main stream. For this distance the small valleys are more open than they are higher up-stream and the side-slopes are no steeper than those facing the South Branch itself. In the second portion of their courses the broad flood-plains become more constricted, the steepness of the side-slopes increases, and the stream channel becomes rocky or filled by boulders whose size often indicates that they have rolled from the neighboring slopes, since they are too large to be moved even at flood stage by the stream whose channel they obstruct. Above this zone of rapids the streams are again characterized by flat, alluvial

plains, bounded by steep, rounded hills, which rise sharply from the surface of the latter to heights of one hundred or one hundred and fifty feet above the meandering channels.

The bottom-lands themselves are composed mainly of black loam with sand, gravel, and irregular fragments. They are well exposed in sections made by the shallow gravel-floored trenches, from one to three feet deep, which the meandering streams have incised in them. These valley floors in the upper courses of the side-streams are due to washing-down from the hills of such quantities of soil and rock debris that the small streams fed by perennial springs in these valleys are unable to keep their courses free.

The South Branch and its tributaries as a whole do not exhibit any striking *degree of adjustment* to the general structural features of the area of that portion of the Piedmont Plateau which they drain. The foliation and various lithologic bands have a general northeast and southwest strike, across which all the streams except the smaller tributaries flow indifferently eastward and southeastward. Definite examples of minor adjustment are not recognized except in the case of a small stream entering from the south at Marriottsville, but the most probable cases are all located on the south side of the Branch. These streams are all of small size, the longest being hardly more than five miles in length, and have their lower courses in general accord with the strike of the foliation of the rocks.

At Marriottsville a small stream about three miles long has developed along the narrow band of marble which extends south from the town for about ten miles. The stream follows the marble closely and has developed a level-floored valley much like the smaller tributaries described below. Although a subsequent stream, it has not as yet captured all the territory covered by this belt of yielding marble, nor are the remaining six miles or so to the south occupied by subsequent streams, as might be expected. Small branches of the Little Patuxent headwaters cross it in obviously fortuitous paths and a branch from the Middle Patuxent, somewhat larger than the stream at Marriottsville, also sends out branches which cross and recross the lithologic boundaries without regard to the character of the rocks.

A striking instance of non-adjustment is found in the case of Winter Run, which rises in the area between the South and North Branches and pursues a general east-southeast direction to Marriottsville, where it joins the South Branch. The upper two-thirds of the valley are broadly open, rather shallow, and characterized by a flood-plain of moderate width which is sometimes rather boggy. The course of the stream and of its small tributaries is everywhere at variance with the general strike and structure of the gneiss. This discordance becomes more marked where the stream is observed to have chosen and persisted in what proved to be a difficult path across a broad band of steatitic serpentine, through which it has had to cut a narrow gorge. If the stream had been free to choose it could have found much easier paths on either side of the band.

The difficulty with which the Winter Run gorge is being cut down shows very clearly that the extensive headwaters of the Run were not developed after the stream had cut its way back across the gneiss and the serpentine, for had such a process been necessary some stream starting on the marble would have developed faster and would now be the main stream instead of the present Run.

North Branch.—The North Branch of the Patapsco, which rises in the vicinity of Westminster, occupies in its upper course a relatively broad, shallow valley, bounded by steeply sloping, rounded hills that rise one hundred feet above the small run at the river's source. Opposite the source is a low sag in the usually even crest of Parr's Ridge, which forms the divide.

The North Branch is characterized throughout by a *flood-plain* of very moderate width, whose general characters vary but little from one portion to another. For several miles down-stream from the source, and to a considerable extent along the headwaters themselves, there is a relatively broad plain of decidedly marshy character that has not been developed as the result of retarded down-cutting in the channel as was the case on the headwaters of the South Branch. This is more probably due to the dams which have been built both at Tannery Station and higher up at Westminster.

As the valley begins to expand, forming the broader reach between

Patapsco and Glen Falls, the flood-plain widens into rich, fertile meadows two or three feet above the level of the winding stream at the usual stage of the water. Where the gorge makes a decided curve the meadows become broadly developed on the convex side and sometimes a terrace ten to fifteen feet above the flood-plain is preserved there also. The broad, flat meadows accompany the North Branch as far as Glen Falls Station where, at the confluence with Glen Falls and a small stream from the north, they unite with the flood-plains of the latter streams and form a broad, triangular plot of moist meadow-land.

Before passing on to a consideration of the lower course of the North Branch mention may be made of the sets of *river terraces* which have been developed along the portion of the stream just described. Two well-marked terrace levels stand above the broad meadow-lands and occasionally three may be distinguished. The lowest terrace, which is not always found, stands four or five feet above the meadows and is most often seen where the stream has cut an ox-bow channel behind a higher portion of the meadow-land, leaving an isolated remnant of a former flood-plain, which is not now submerged even during the heaviest floods. Examples of this terrace, which is largely composed of loam and fine gravel mixed with sand, may be seen along the Western Maryland Railroad between Finksburg and Patapsco Station.

The second terrace stands about ten feet above the meadows and five or six feet above the first one, and is built of coarser quartz gravel, sand and loam. This terrace is from thirty to fifty feet in width, and a very persistent feature as far as Glen Falls where it merges with certain terrace gravels belonging to the Glen Falls terrace.

On the steep hillside eighty or ninety feet above the stream channel is the third terrace represented by limited areas of water-worn gravels and rounded or sub-angular pebbles. The quartz, gneiss, and quartzitic rocks which contributed the materials of these thinly spread deposits, as well as the materials of the lower terraces, occur in the immediate vicinity. As there are no traces of water-worn deposits

upon neighboring hilltops it is probable that the gravels of this highest level were supplied from fragments obtained in the immediate vicinity of the stream. The absence of any traces, upon the hilltops, of the Lafayette does not, however, prove that these gravels do not represent the worked-over remnants of such a deposit. On the contrary it is quite possible that they are the only remaining evidence of the former presence of that formation in this district.

Below Glen Falls the terraces decrease in importance, usually being absent or developed only where some broad swing in the course of the stream has left the old flood-plain on the convex side of the curve. As a rule, only a single terrace is found, corresponding in elevation to the second one in the series of the upper portion of the stream. At the mouth of Beaver Run, two miles south of Finksburg, the broad flood-plain of the Run joins the relatively narrower one along the North Branch and lies about twenty feet below a broad, flat, sandy terrace, forming the point between the Run and the North Branch. Again, two miles north of North Branch Postoffice a mill has been built on a flat terrace, twenty feet above the channel, which passes around it in a broad swing. The section which the stream makes where it cuts through the terrace shows that the latter is composed of water-worn cobbles, gravel and pebbles, generally iron-stained and overlaid by two feet of angular fragments of the black hornblendic schist which forms the neighboring hills. The last locality where the terrace gravels were seen before reaching the confluence with the South Branch was half way between the latter point and North Branch Postoffice. At this place a stream of moderate size, which rises on the land between Hernwood and Harrisonville, empties into the North Branch just east of a low knoll of marble. On the crest of this marble knoll and extending down its slopes for ten or fifteen feet is a thin veneer of gravels and pebbles closely resembling in lithologic characters the materials of the second terrace found along the upper course of the North Branch. At the southern foot of the knoll the North Branch makes a smooth swing to the northeast and east in a muddy and sandy flood-plain, which the small side-stream has helped to build.

The *small tributary streams* which combine as the headwaters of the North Branch and others near Patapsco Station flow at the bottom of relatively deep ravines. Their channels are usually somewhat winding as they occupy narrow flood-plains strewn with angular fragments which have rolled from the surrounding slopes. Sometimes a stream crosses a band of quartzite or a quartz vein and then the little valley grows narrower and the channel steeper. Generally the headwaters of these small side-streams are characterized by open, shallow catchment basins which form but slight depressions and belong to the rolling surface of the Piedmont upland. Those larger streams which join the North Branch along its lower course generally correspond more closely to the types illustrated by Glen Falls and Winter Run, while the sides of the gorge, particularly along its lower course, are serrated by small brooks of uniformly steep grade confined between high, steep banks. These latter streams do not take their rise any considerable distance back upon the plateau.

Glen Falls, which is a stream about four miles in length, heads in the vicinity of Glen Morris and Emory Grove. It begins as a small rapid rivulet, flowing in a narrow wooded ravine, but within a mile it is joined by several side-streams which swell its volume to a run of some size. Simultaneously with this increase in volume of the stream the valley widens and the flood-plain develops, gradually increasing in width until it merges into the broad meadows at the confluence with the North Branch. The side slopes of the stream are steep and rounded, and descend sharply to the surface of the flood-plain.

One of the interesting tributaries of the North Branch is the small stream already referred to as rising between Hernwood and Harrisonville and joining the North Branch between North Branch Postoffice and the confluence. This stream, though having its headwaters situated on the gneiss of the Piedmont, follows throughout most of its length a subsequent course located on an S-shaped band of marble. This marble band appears to be a detached portion of the long strip of marble which stretches southward from Marriottsville and, like the latter, has a band of quartzite along its eastern edge. On the marble the stream has developed, by the solvent action of its

own waters and the ground-waters which gradually drain into it, a wide, level-floored valley of rich alluvial soil. Below this meadow-land the Run has sunk its channel from two to ten feet, the amount increasing down-stream. At the highest floods it does not appear that the meadow-land is extensively submerged, although the trench is evidently filled. Twenty or thirty feet above the meadows a narrow level bench runs along the valley-slopes, coinciding approximately with the line between the marble and the gneiss. This bench is somewhat better marked on the northwest side of the valley. On the southwest side the band of quartzite causes the whole southwestern slope to rise more steeply than does the opposite one.

At the mouth of the stream a marble knoll, rising thirty-five feet above the channel, embraces nearly all of the area occupied by the marble. On the west of this eminence is a small side-stream, while on the east the main stream cuts its course across a resistant band of

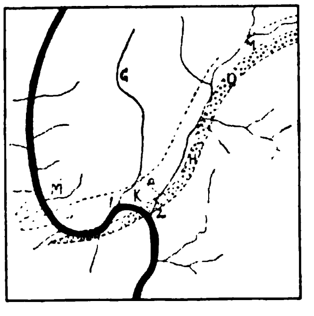


FIG. 20.—A minor adjustment in a side stream of the North Branch of the Patapsco.

quartzite and the gneiss beyond, which lie on the eastern border of the marble. Behind the knoll between these two valleys is a low saddle which is not covered with stream gravels. Through it now passes the road from Hernwood to Marriottsville. An explanation for the relations existing between the gravels capping the marble hill, the location of the run on the quartzite, and the saddle in the marble behind the knoll, is shown in Fig. 20.

The low marble knoll at *K* standing thirty feet above the present level of the stream, is capped by a thin veneer of Pleistocene gravels, while at the same elevation, along the sides of the marble valley of

stream *H*, are benches in the marble and sometimes even slight cuts in the gneiss. Moreover, the elevation of these gravels and terraces coincides with the better-defined and more-widely distributed terrace found along the North Branch of the Patapsco. It is, therefore, probable that in Pleistocene time the stream valleys stood near he three hundred-foot contour within the territory included in the figure. At that time the heavily loaded streams brought down quantities of sand and gravels, some of which was deposited on the triangular area about *K*. Over the flood-plain thus formed the streams *G* and *H* entered the Patapsco by some common channel perhaps between the points *1* and *2*. While building this flood-plain and the level expansion of the three confluent valleys the combined forces of the streams had reduced the marble, the gneiss and the quartzite to an approximately even surface, so that at the close of the gravel-depositing period the three varieties of rocks were buried beneath the gravels and sands of the streams.

When the elevation and tilting occurred, which closed the Pleistocene deposition and revivified the overloaded and sluggish streams, *H* and *G* were incised below the flood-plain while they held a position vertically above that which they now occupy, except that *G* instead of entering the Patapsco at *1* turned eastward and joined *H* by the dotted course, *a*, and thence flowed with the latter stream to *2*. The streams cut rapidly through the old flood-plain which served to guide them for a time in their down-cutting. When the foundation of marble and quartzite was reached the deepening of the channels went forward more slowly but continued until they also were reduced to a grade about ten feet above the present channel. When this position had been reached vertical corrasion seems to have ceased for a while and the streams gave more attention to the widening of their valleys, as recorded in the broad lower portion of the valley.

In spite of the retarding influence of the quartzite, *Q*, on the downward-cutting of *H* and the opportunity which was thus given for a stream to start on the marble at *1* and work back to the elbow of *G* just above *a*, it would seem that *G* persisted in its course at *a* almost up to the time when *H* began to broaden its valley, because the floor

of the notch at *a* stands at almost as low a level as does the floor of the valley about *H*. While this deepening of *H* and *G* was being accomplished a small stream at *1* was slowly working away the gravels of the Pleistocene flood-plain and the marble flooring beneath them, gradually extending its head back towards *G*. The rate at which it could develop and deepen its course was not as rapid at first as was that of *G* and *H*, because these two streams were already established and of great volume, while *1* was small and had heavy loads of gravels to remove. Both the large and the small streams flow into the same master stream, the Patapsco, whose large volume and great power enabled it to maintain its channel at a very low slope, so that there was no essential advantage, due to differences in the relative height of local base level, possessed by the stream which emptied into the river lower down. Thus the controlling factor in the rate of development of the two streams came to be a lithologic one, and the speed of down-cutting was determined by the relative resistances of the marble and the quartzite. In this respect the small stream starting at *1* had an advantage over *H* — *G*, since the former stream was located on the easily degraded marble , while the latter stream had to reduce both gneiss and quartzite before the marble could be brought to as low a level as the channel of the Patapsco.

With the advantage of being located on the marble from mouth to source *1* was able to work back and cut down so rapidly that it tapped the channel of *G* before *G* and *H* combined could quite reduce the resistant bands across their common mouth. Thus *G* was diverted from its course at *a* and led out by an easier path, while its old channel remained as a dry pathway and a low wind gap behind the knob *K*. A second uplift of lesser degree caused both the streams to trench the valley-floors which they formed after the first post-Columbia tilt, so that at present *H* is cutting a steep, rough gorge, now ten feet deep, through the quartzite and gneiss, while *G*, on its marble floor, has rapidly widened the new trench it cut until there are very slight traces of the old valley level left along its course.

Main Stem of Patapsco.—From the confluence of the North and the South Branches to the head of the estuary of the Patapsco, the

river occupies a well-marked gorge, which is sunk three or four hundred feet below the general level of the plateau. The steep sides, narrow flood-plain and rocky channel of this portion of the stream's path are well illustrated by the accompanying views, Plate X, which show the gorge in the vicinity of Ilchester and also at the mouth of Brice's Run. The features above enumerated continue without material change to the bridge at Relay, where they give place to the corresponding features developed by the stream on the less resistant sediments of the Coastal Plain. Throughout the Piedmont stretch the channel is characterized by numerous low rapids, particularly between Ellicott City and Relay, where the channel is frequently crossed by pegmatite dikes, of greater or lesser width, whose superior resistances, when contrasted with the foliated gneiss, etc., cause them to stand out as low sills across the channel. Between the sharper pitches of the channel often come stretches of rapidly flowing but unruffled waters, whose smooth surface reflects the luxuriant vegetation of the banks and adds greatly to the beauty of the stream. These quiet stretches grow longer and more frequent in the gorge above Hollofields and there accompany a slight decrease in the grade of the channel. Just at Relay the gorge widens suddenly and rapidly like the flaring mouth of a trumpet, sending the stream out into the broader valley which it has carved on the Coastal Plain. Here the stream ends its troubled course and occupies a broad, level-floored valley, bounded by lower and more gently sloping hills with terraced slopes.

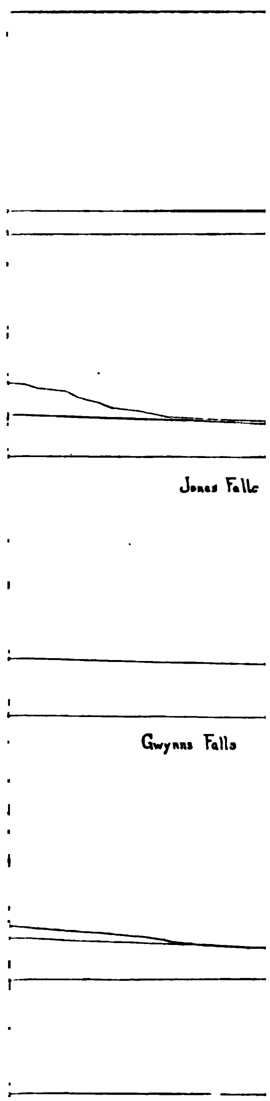
There are very few examples of *terraces* along the rock-walled gorge of the main stream. Where the river crosses a T-shaped marble band at Alberton is the best and, perhaps, the only occurrence of a terrace which this portion of the Patapsco valley can show. A few hundred yards above the village the gorge suddenly broadens to a width of a quarter of a mile between its higher banks. At the same time the channel suffers a slight change in its position, so that the stream running against its south bank is there bounded by steep slopes of the gneiss rising one hundred and fifty to two hundred feet above it, while on the north it is seen to lie not more than twenty-

five or thirty feet below a gravel-strewn bench, whose former even surface is now somewhat dissected by the numerous gullies and small waterways which are eating into it. This bench completely occupies the widened gorge except for the narrow trench whose floor is formed by the present channel and flood-plain. The overlying gravels are thinly strewn over it and mixed with the rich soil produced by the decomposing limestone. The pebbles are not of large size, as a rule, and usually consist of sub-angular or partly rounded fragments of vein quartz. At the down-stream corner of this terrace a slight eminence rising from it suggests a second and higher level.

The other terraces along the lower course of the Patapsco are found only after the river has left the narrow gorge and has entered the broader valley by which it crosses the edge of the Coastal Plain. Below Relay the river emerges into a broad amphitheater-like space which is bounded by low hills of the Potomac formation and the Pleistocene. The stream loses its troubled features and becomes a gently flowing current which swings in broad curves over an alluvium and gravel-covered flood-plain. The present channel and flood-plain is immediately overlooked by two terraces built of Pleistocene gravels and sands. The lower terrace has an elevation above stream channel of about fifteen feet, and is perhaps a quarter of a mile wide where best developed, *e. g.* in the vicinity of Elk Ridge Landing. The broader and more strongly marked terrace stands about forty feet above the present channel and attains a width of half a mile just below the Baltimore and Potomac Railroad.

Both these terraces may be traced from their beginning at Relay down to the shores of the harbor where they form topographic features for a short distance along the water-front. The higher terrace may also be traced for some distance up the valleys of Deep Run and the other small streams which join the Patapsco between Relay and Elk Ridge.

The type of the *tributaries* which flow into the lower course of the Patapsco is represented by Brice Run. This is a stream about five miles in length which flows southward from Randallstown and the Liberty Turnpike to join the Patapsco about half a mile above Alberton.


Jones Falls
Gwynns Falls

The fan-shaped area which is drained by this stream is characterized by an intricately developed drainage scheme whose broad, shallow valleys are bounded by gently sloping hills and floored by medium-sized flood-plains. The valley increases gradually in depth until about a mile from its mouth, when it begins to deepen and narrow rapidly. The stream channel itself in this lower gorge is filled with fragments from the sides of the valley and is comparatively steep, averaging forty-five feet to the mile. There is a narrow flood-plain even in this portion of the course, but its deposits of loam and alluvium are very thin, and it is largely formed of angular fragments of the gneiss, as is the channel.

The broad, open heads of the valleys, combined with the deep, narrow lower courses, are clear indications that relatively recent uplift has taken place along the zone covered by streams thus characterized. The Patapsco has since this uplift been able to cut its channel down almost to grade again, and this in a comparatively short time, because of its relatively greater volume. The side-streams having less volume and consequently less power have not been able to work as rapidly as the large stream, so that their upper courses still remain unaffected by the uplift, while their lower courses show the trenching which resulted from the change in level.

Channel Profile.—The accompanying drawing, Plate XIX, shows the vertical elevation above mean tide of the Patapsco, of its two branches and of the streams which head against them on the western slope of the divide of Parr's Ridge. The drawing includes the whole of the South Branch, the course of the main stream, and a part of the North Branch with its main tributary, Morgan's Run. As the data for completing the grades of Linganore Creek and Bush Creek were lacking they were carried only to the Monocacy.

The drawing shows that the Patapsco and its branches agree in general with the other streams of the eastern Piedmont district. The channel grade is on the whole very mild as compared with that of the western Piedmont streams. The South Branch, which is of less volume than the North Branch, is shown to have the steeper grade of the two. This is in accord with the general law that, other

things being equal, the stream having the largest volume of water will reduce its channel to the lowest grade. In comparing the grades of these two streams it is well, however, to bear in mind that the North Branch has a considerable portion of its lower course arranged parallel with the strike of the foliation of the gneiss. The relation of volume to grade is brought out very clearly on comparing the grade of the Patapsco with those of the smaller Piedmont streams. Streams like Jones' Falls and Gwynn's Falls show a decided convexity upwards along that portion of their grades which just precedes their passage out into the Coastal Plain province. This feature is by no means so pronounced in the profile of the Patapsco, although the vertical exaggeration of the latter is twice as great as that of the two former streams. The milder grade of the Patapsco is due to the fact that with its larger volume it has been able to reduce its channel to a much lower level and a smoother course than it was possible for the smaller streams to do in the same length of time. That a perfectly graded course has not been attained, as yet, even by the large streams, is shown by the low falls which still characterize their channels and by the slight upward convexity of the profile.

GENERAL CHARACTERISTICS OF THE PIEDMONT STREAMS.

Stream Patterns.

The general system of division and subdivision followed by the streams of the Piedmont Plateau has been likened to the manner in which the trunk of a tree divides and subdivides. From this resemblance the system is known as *dendritic*. In the particular case of the streams which have been considered in the preceding sections the general alignment of the main streams, or the trunks of the trees, is southeastward towards Chesapeake Bay. The streams flowing into the Monocacy follow a general westward direction. Since the drainage of any district normally tends, from the very first, to arrange itself along lines determined by the distribution of the rocks encountered, it is evident that the history of many of the streams of the Piedmont are somewhat abnormal, as they very rarely follow courses which are in accord with the structure. The most striking cases of divergence are furnished by the larger streams, such as the Big Gunpowder, the

Patapsco and the Monocacy. Equally significant examples, however, are found among some of the tributary and smaller streams. For example, the dendritic headwaters of Western Run are strikingly out of adjustment with the long, narrow bands of gneiss and marble lying across their paths. The whole course of Deer Creek is at variance with the relative resistances of the quartzite, the gneiss and the serpentine bands across which it flows. About the small head-streams of the Patuxent there are ample opportunities for adjustment in the presence of several bands of soluble marble, but only the very smallest rivulets have assumed subsequent courses.

The small streams at the very head of the West Branch of the Gunpowder, the corresponding streams of the North Branch of the Patapsco, Little Deer Creek, and several small streams on various marble areas include most of the noteworthy instances. There is, however, a rather numerous class of streams, like Jones' Falls, Western Run, and the westward flowing tributaries of the Monocacy, which show a partial adjustment to the rocks of their drainage basins.

Valleys.

From the facts just given it follows that the valleys of the streams naturally fall into two main groups, viz.: (1) valleys which are entirely at variance with the general structure and, (2) valleys which conform more or less completely to the variations in the rocks. The two sets of valleys have rather different characters in certain portions of their courses.

All those streams whose headwaters do not lie in subsequent valleys are characterized in this portion of their course by comparatively broad, open and shallow basins lying comparatively close to, if not actually on, the upland surface. As these streams descend their valley-walls gradually close in, their side-slopes steepen and within eight or nine miles of their mouth they enter narrow, steep-sided gorges which continue until the streams reach sea-level.

Those valleys which are determined in their location by the presence of yielding rocks, and therefore belong to the class of subsequent valleys, may be again subdivided into two classes. One class includes the valleys made by the streams which now occupy them. These are

represented by Little Deer Creek, and Broad Creek above Pylesville, and Long Green Valley. They are peculiarly distinguished by the very commonplace fact that the streams traverse them from end to end, longitudinally. The second class consists of those valleys which apparently were not fashioned by the streams now traversing them. These are peculiarly distinguished by containing the remnants of an earlier filling and by the fact that the streams draining them usually *cross* them transversely. The class is represented almost solely by the irregularly outlined depression embracing Green Spring, Dulaney's, Mine Bank Run and Cockeysville valleys.

Channel Profiles.

Comparative studies of the channel profiles show that the Piedmont streams possess several peculiarities. In the first place, their channels do not possess the normal profile curve throughout as this is typically represented in Fig. 3; secondly, the divergences from the normal profile occur altogether along the lower courses of the streams; and, finally, the profiles of the westward flowing streams are found to be both steeper and more nearly normal than those flowing eastward.

The fact that these stream profiles do not show the normal channel curve throughout their extent is a clear indication that there has been at least one interruption in the uniform development of the streams, and this interruption has been of the nature of a general uplift, or series of uplifts, since only that could cause the lower courses of the numerous eastern streams to show the convex-upward profile which is characteristic of immature streams, while the upper courses of the streams retain the mature concave profiles developed before the uplift. Moreover, there is an obvious and close connection between the steep, narrow gorges, which belong to the lower courses of all the Chesapeake streams of the Piedmont, and this convexity of the lower portions of their channel-grades.

Even more interesting, however, is the comparison of the profiles of the streams on either side of Parr's Ridge. It has already been remarked that the Monocacy tributaries have much steeper grades just at the divides. They also are of much milder grade in the middle and lower sections of their courses, and reach a lower elevation

more rapidly than their eastern opponents. This marked contrast in the grades of the two sets of streams is evidently due to a common cause. The Monocacy flows, throughout most of its course, either on limestone or on the yielding Newark formation, while the eastern Piedmont streams have by no means such an easy path. Thus the Monocacy and its tributaries have always kept their lower courses close to the mild, low grade of the powerful Potomac, and have been able to push back their headwaters vigorously against those of the other streams.

These present conditions suggest a new explanation for the formation of Parr's Ridge involving the relations between the rocks of the eastern and the western Piedmont during the production of the Schooley peneplain. Then, as now, the Potomac river was the great master stream of the whole Province and was able to maintain a comparatively low grade. The present distribution of the Newark and of its remnants, taken in connection with various discordant drainage features among the eastern tributaries of the Monocacy, indicate that the Newark formation formerly extended farther east towards what is now Parr's Ridge.

Granting that the Newark formation had an even greater extent in Jurassic time than it has to-day, and understanding from present profiles what advantages the Potomac tributaries possess, it must be conceded that the Monocacy river, or a closely similar stream, occupied a subsequent valley on the Newark. Such being the case, the eastern tributaries of that stream must have had advantages over the eastern Piedmont streams in those times just as they do to-day. It therefore seems probable that Parr's Ridge remained as a low divide during the formation of the Schooley peneplain.

HISTORY OF THE PIEDMONT STREAMS.

Origin.

Any account of the origin of the streams of the Piedmont Plateau must, in order to be satisfactory, explain the several seemingly anomalous characteristics which they present. The chief of these anomalies is the fact that although the streams are well developed yet they show an almost total disregard for the underlying rock structure.

Lesser peculiarities are the minor discordances and adjustments, and the peculiar location of a number of streams against the southern or southeastern limit of their valleys.

The discordance between the streams and the structure of the Plateau is so wide-spread that some wide-spread cause is necessarily required to explain it. Such wide-spread discordances can only result from the streams cutting down through a broad blanket of some sort which hid, at the time of the origin of the streams or early in their history, the structure and topography later discovered. Thus the broad loess deposits of China and of the central United States serve as such covers through which the streams of to-day have already cut or are cutting their way down to the underlying rocks. The broad sheets of glacial till of the north, or the less extensive lacustrine clays of Lake Agassiz or Lake Bonneville, serve the same purpose for their respective regions. The deep mantle of disintegrated material which forms the soil and subsoil in more southern districts might also serve as an agent of superposition. It is of a comparatively uniform degree of resistance, thus resembling the glacial and lacustrine deposits and producing similar drainage patterns for the streams which originate on it.

In the partially removed cover of Coastal Plain sediments there is ample evidence of a past ability to produce such a phenomenon, provided there is enough evidence to warrant the conclusion that the Coastal Plain has thus served the drainage of the Plateau. To prove this it must be shown—

1. That the Coastal Plain has covered those portions of the Plateau which now show discordant drainage.

2. That the superimposed drainage, if it came from the Coastal Plain, ought to have its general direction in accord with the drainage lines of the latter and its general pattern of the same type.

There is some evidence favoring the first condition in the occurrence of several outlying remnants of the Coastal Plain deposits. To this may be added the just conclusions, based on considerations of the lithological characters of these sediments that they once extended farther west, and that they do not now occupy exactly their

old shore-lines. Both of the features required by the second condition have already been shown to be characteristic of the major portion of the drainage under consideration. It therefore seems a true conclusion that the streams of the eastern portion of the Piedmont Plateau originally took their courses on the surface of the Coastal Plain; that the streams cut down through this cover and laid bare the old surface of the Piedmont region, at the same time establishing themselves thereon in courses out of harmony with the varying lithologic character of the region.

Minor Discordances.

The Pleistocene subsidence of the lower courses of the streams permitted the contemporaneous accumulation of broad, gravelly and sandy flood-plains, occupying the valleys of Western Run, Dulaney's Creek, Mine Bank Run and Beaver Dam Creek, as well as Green Spring Valley. It is a well-understood fact that when a river has reached the flood-plain building stage, it is in a state of delicate balance, so that a very slight disturbing element can cause the stream to shift its course very decidedly. With this in mind, the unsymmetrical location of the streams in the valleys mentioned, and the sometimes discordant positions which they have taken, may be explained as follows. The Pleistocene period of flood-plain building was brought to an end by a general elevation which was of the nature of a tilting towards the southeast. This tilt caused all the east-and-west and northeast-southwest streams to slide over their flood-plains southward or southeastward. Thus Dulaney's Creek and its companion became located upon the ledge of gneiss which they had reduced; the streams in the northeastern portion of Mine Bank Run valley shifted over upon the pegmatite dike; and Western Run, Piney Run and Jones' Falls took their present positions along the southern limits of their valleys. The elevation which accompanied the tilt revived the streams and caused them to trench their channels below the Pleistocene flood-plains, thus initiating the period of active erosion which caused the convexity of all the eastern stream profiles.

Recent Changes.

Since the Pleistocene deposition and post-Pleistocene elevation, further adjustments have probably gone on, the streams have incised themselves more deeply in the positions which they inherited from the tilted flood-plains, and there is a general tendency to reduce the stream-grades as rapidly as possible.

CONCLUSION.

The results of the study of the Piedmont Plateau drainage may be summarized as follows:

1. The streams of the eastern division of the Piedmont Plateau have been superimposed from the formerly more extensive Coastal Plain cover.

2. The date of this superimposition is probably post-Lafayette, although there are some facts that point to its initiation in post-Potomac time.

3. Secondary superimposition from Pleistocene flood-plain deposits in *subsequent valleys* show that recent elevation has been accompanied by a tilting toward the southeast.

4. The westward extension of the Coastal Plain, as evidenced by the discordant drainage which it produced and by sedimentary records, cannot be traced with certainty west of Parr's Ridge.

5. The minor cases of discordance which occur in the drainage of the Monocacy are the result of superimposition from the Newark formation.

6. Parr's Ridge has been, as it is now, the divide between Monocacy and Chesapeake Bay streams since late Jura-Trias times; it is being gradually shifted eastward because of the greater activity of the Monocacy drainage; and it represents, not a part of the plain-surface, but a low, minor divide on the Schooley peneplain.

PART III

REPORT ON THE

METEOROLOGY OF MARYLAND

PREPARED BY DIRECTION OF

WILLIS L. MOORE

CHIEF OF U. S. WEATHER BUREAU

BY

CLEVELAND ABBE, O. L. FASSIG, AND F. J. WALZ

THE AIMS AND METHODS OF METEOROLOGICAL WORK

ESPECIALLY AS CONDUCTED BY

NATIONAL AND STATE WEATHER SERVICES

BY

CLEVELAND ABBE

INTRODUCTION.

In response to the request of Professor Wm. B. Clark and the instructions of Professor Willis L. Moore, Chief of the U. S. Weather Bureau, the following paper has been prepared, embodying some remarks "On the Aims and Methods of Meteorological Work, especially as conducted by National and State Weather Services." As it was desired that this report should be suggestive of new lines of work for the Maryland State Weather Service, I have made it bear more especially upon that state, and have included many details instead of limiting myself to general statements. I have borne in mind the statement of the Director of the Maryland State Weather Service:—

"It is the desire of the State Weather Service Board for Maryland to expend the energies and money of the State Service in the direction of climatological work rather than in the mere accumulation of meteorological data, as in the past. It is the intention to enter into the study and discussion of special problems connected with climate and its effects, and to take up certain lines of climatological research and investigation which it is thought will be of interest to the people of the State."

As the weather and the climate enter intimately into every aspect of human life, the field that is before us is one of exceeding great extent and probably no single weather bureau need attempt to compass the whole. The principal applications of meteorology to which we must call attention at present are those concerning hygiene, agriculture, commerce and the mechanical arts.

Local state services have generally been established in order to attend to the numberless minute details that it was reasonable to suppose could not be looked after by the Weather Service of the general Government. Some of these special studies have already been taken up in Maryland but other questions still remain, and at the risk of being prolix, we shall enumerate many of these, in order to collect in one essay a list of the most prominent fields of usefulness as suggestions for the future development of the Service. The Maryland State Weather Service is established on a basis as broad as that of the Maryland State Geological Survey and will be recognized as fully competent to convert its store of scientific knowledge into practical rules that will benefit every human interest. The service will always bear in mind that its highest duty is to discover and utilize all that can be found out about the local weather and the diverse climates of every spot in Maryland.

A State Weather Service that is conducted as a section of the general Climate and Crop Service may have a special range of activity prescribed for it by the Chief of the Weather Bureau, but a service that has a separate existence, as in the case of the Maryland State Weather Service, is liable to be called upon by the citizens who contribute to its support for information in any and every field and is in duty bound to adopt such methods of work as will bring the value of its best results home to every citizen.

When we survey the work of the fifty or more official national weather bureaus that are now serving the interests of civilization throughout the world, we perceive that, in almost every case, the duty that is recognized as being of first importance is the prediction of the daily weather and, if possible, the seasonal climate and the fore-warning of important storms, cold waves, frosts, rains, etc.

The next most important duty, but in many cases that which in order of time was the first, is the collection of the data needed to define clearly the peculiarities of climate throughout the whole extent of each state.

Modern climatological work began with the establishment, in 1653, by Ferdinand II, Grand Duke of Tuscany, of a system of meteorological stations in northern Italy which were furnished with thermometers that accorded with those used by the *Academia del Cimento*, and their indications can be converted into those of the modern thermometer by means of the comparisons made by Libri in 1830.

But from the earliest ages the study of climatology has also been pursued without the use of such instruments, and if we desire to compare ancient climates with modern, we must (for this purpose only) revive ancient methods as closely as possible. A remarkable illustration of this principle will be found in a recent publication on the climate of Athens by Prof. D. Eginitis, Director of the Royal Observatory at Athens; this author compares the instrumental records of the past forty years with the statements that he has been able to gather from classical writers as to the climate two thousand years ago and finds, as we might expect, that there has been no appreciable change. Among other interesting illustrations, we may refer to the record kept by William Merle of Merton, England, from 1337 to 1344, which was, a few years ago, discovered and reprinted in facsimile by Mr. G. J. Symons; the discussion of this record again shows that the weather was the same then as now, or rather that, if there has been any systematic change, it is of such a slight character that the weather records do not reveal it.

It follows from the preceding, that we are justified in combining together into one general view, or normal value, any observations that may have been made over a very long period, without fear that we are thereby forming a heterogeneous mixture. In fact, we may let all questions as to possible or theoretical change of climate remain in abeyance and proceed in the firm assurance that the climate has not and will not change, no matter how variable the weather.

The great extent of the problems covered by the title of this

report suggests that we divide it into three sections: Dynamic Meteorology and its applications; Climatology and its aims and methods, in relation to agricultural and other interests; Observational Apparatus and Methods.

DYNAMIC METEOROLOGY AND ITS APPLICATIONS.

Introductory Statement.

The title of this section brings before us two essentially different subjects, namely, a difficult branch of theoretical science and an important field of applied science.

The national weather services, now conducted by every civilized nation of the globe, deal primarily with the atmosphere as a whole. The storms and weather changes proceed upon too large a scale to be handled by a single nation. The best that each can do is to compile its own daily weather map for its land and ocean areas and then join them all together into one map that shall fairly represent a large portion of the earth's surface. Such general maps form the basis for the proper study of dynamic meteorology.

On the other hand, both large and small weather bureaus must busy themselves with the special study of their own local climatic conditions and their relations to all branches of human industry. All meteorological work resolves itself into two grand divisions, namely, general dynamic meteorology and local climatology. Climatology deals especially with the atmosphere at the earth's surface; dynamic meteorology must, necessarily, study the whole atmosphere to its outermost limits and over the whole earth's surface. This study is necessarily and essentially observational and mathematical, since the atmosphere as a whole can not be subjected to laboratory experimentation. Hitherto, the practical applications of our knowledge of dynamic meteorology have proceeded with but little help from the more difficult mathematical theory; they have necessarily proceeded on the so-called empirical basis. It was considered necessary that weather predictions should be made daily, and it was found that use-

Fig. 1.—CIRRUS CLOUDS.

Fig. 2.—CIRRO-STRATUS CLOUDS.

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ful work could be done without waiting for the development of our knowledge of the mechanics of the atmosphere. But it is now demanded that the good work thus far accomplished shall be followed by still better, and there is no hope of accomplishing this except by perfecting our knowledge of the higher science.

This first section will deal largely with the so-called practical work of national and state weather services; but at the close we shall say a few words with regard to analytical and experimental research.

The General Features of National Work.

In considering the actual work and objects of the national weather bureaus, we note that on account of its large proportions and the multiplicity of its operations, our United States Weather Bureau is typical of the many others established throughout the world. Some pay special attention to one feature and some to another, but each is endeavoring to work out the problem of the greatest usefulness to its own local government and people. In general, we may say that the daily weather map is the basis of the usefulness that is the common aim of all national organizations. For Germany, France and the interior states of Europe, the prediction of local thunderstorms has been made a prominent study. In the United States, the prediction of frosts, blizzards, and cold waves is an important feature. In India, the prediction of rain and, especially, of seasonal droughts has been laboriously studied. In Australia, the prediction of both storms and droughts is being attempted. For the tropical islands, Barbadoes and Mauritius, attempts have been made to predict the seasonal rainfalls and their influence on the sugar crop. Everywhere it is considered a primary duty to give abundant warning of hurricanes, typhoons, and other extensive wind storms. The United States is also very successful in the prediction of cold waves, hot waves, droughts, freezes and blizzards.

The national services of Russia, Germany, Italy, France and, especially the United States, have also improved every opportunity to encourage the study of the mechanical principles that underlie atmospheric phenomena and the elaboration of a systematic theory of the dynamics of the earth's atmosphere.

In reply to a circular recently sent to all the weather bureaus of the world a list has been compiled showing the objects kept in view by each of these institutions, from which it appears that with few exceptions, each holds itself in readiness to furnish local weather predictions as to wind, weather, temperature and rain, for any portion of its territory. Each is studying the local climate and its relations to crops, health and the industries of the country; each publishes some form of daily, monthly and annual report; the records of each are recognized as legal and authoritative in all courts of law; each receives daily and other reports by telegraph, both from its own area and from neighboring countries; many support special stations in distant portions of the world, not otherwise provided for; when practicable, each supports one or more mountain stations, or utilizes kites or balloons to study the upper air; in some cases, the meteorology of the ocean is provided for by special marine or naval offices, in others, it is considered a portion of the duty of the weather bureau itself. Frequently, special stations are maintained for the study of the influence of the climate on the cultivation of specific plants, such as cotton, tobacco, sugar beet and sugar cane, cranberry, the grape and wine culture, wheat, maize, oranges, etc.; others make a special study of the damage by lightning and hail, by wind or by rain; some maintain special stations for the temperature of water in rivers, lakes and seas and the study of its relation to fisheries; a few make a special study of terrestrial magnetism or of the diurnal variations of the meteorological elements and their ultimate causes; a few study the quantity and character of the dust in the air and the general relation of the dust and the climate to hygiene; many keep records of the temperature of the earth and its relation to the atmosphere. Stations and services that long since began to observe atmospheric electricity still maintain their registers; nearly all keep some record of the heights of water in rivers and attempt the prediction of floods; quite a number maintain phenological stations at which the periodical phenomena of the growth of plants, such as budding, blossoming and ripening are regularly recorded and studied in their relation to the climate; earthquake observations are made, either crudely

or by means of seismometric apparatus. In general, each bureau maintains a supervision over the condition and work of the subordinate stations; the larger bureaus are provided with workshops and mechanicians for the construction of new and the repair of old instruments; several bureaus report that from time to time, meteorological reunions have been held in which all the higher employees participate. The publications of the bureaus generally appear about the beginning of each year and include, not only statistical data, but also the discussion of the same and the results of investigations into instrumental questions and, sometimes, the theory of the mechanics of the atmosphere; in the colder countries, the bureaus pay especial attention to snowfall and frosts; in most services, the photographic study of the clouds and cloud motions has been taken up. In a few cases, the time service and the investigation of chronometers has been actively prosecuted for the benefit of the marine. In order to predict the character of the monsoon, the Indian Weather Service publishes a daily chart of the Indian Ocean, called "The Monsoon Chart," which has already become an invaluable basis for the study of this subject.

The Development of the Daily Weather Map.

The prediction of the weather from day to day has been recognized as a desideratum from time immemorial, but the realization of this desire was not possible until synoptic daily weather maps began to be constructed. With this specific object in view, the Meteorological Society of the Palatinate, with its center at Mannheim, began in 1780 the collection and publication of detailed meteorological statistics for Europe, adding a few reports from America, and although the ponderous tomes containing these observations ceased to appear after thirteen years, yet they gave the needed stimulus to the proper study of the mechanics of the atmosphere. Based on the data in these volumes, H. W. Brandes made a series of daily weather maps for Europe, for the whole of 1783. The results of his study were published in 1820 in his *Beiträge*. In 1826, Brandes published a second work, *De Repentinis*, in which he studied the storms of 1821, December 26, and 1823, February 23. His stations and maps were not sufficiently numerous to bring out all the details that we are now

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familiar with, but he acquired a clear perception of the relation of the winds to the isobars, and the movement of storm centers, and urged the organization of international meteorological services. His work in Europe was coeval with the earliest work of Espy and Redfield in America. From 1821 until his death in 1857, William Redfield of New York was the next to collect observations and advance our knowledge of the storms. He studied especially synoptic maps of the ocean and enunciated important laws which have always been accredited to him. He first demonstrated by his abundant observations, that which had been vaguely understood for three centuries, since the days of Dampier, and had been partially expressed by Brandes, namely, that the great ocean storms have both a rotary and a progressive movement. James Espy followed Redfield, chronologically, in the construction of maps, although as an author on various points in meteorology he had published much before. About 1822, Espy seems to have grasped the idea that the latent heat evolved in the condensation of moisture must make a cloud specifically lighter than the air surrounding it; that it must, therefore, be buoyant, and that as it rises other air must flow in to take its place. To him, therefore, the cloud seemed to be the active center that when once formed draws air up to itself. He applied this idea to waterspouts, tornadoes and thunderstorms and then set about collecting data to test this theory. His first maps of the storms related chiefly to the winds and seemed to show the centripetal tendency. But his wider application of this idea led him into an unfortunate controversy with Redfield. Espy made the mistake of assuming that what is true of small storms on the land would be equally true of the large storms on land and ocean. Redfield granted that in his large ocean storms the winds showed a slight centripetal or spiral movement, but maintained that the principal and important component was the circular movement. Between 1838 and 1848, Espy greatly increased the number of his meteorological correspondents throughout the United States and compiled an almost continuous series of daily weather maps. His enthusiasm moved his friends in the U. S. Congress to appoint him, in 1842, as Government Meteorologist, and he was at first assigned to

duty in the office of the Surgeon-General of the Army, which was at that time the principal repository of meteorological observations for climatological studies. But Espy did not interest himself in climatology, and after several years of mapping and studying storms, he was assigned to duty under the Secretary of the Navy, in order that his work might be extended over the ocean and made useful to navigators. About 1848, although borne upon the rolls of the Navy Department, he was ordered by Congress to prosecute his studies and complete his report under the guidance of the most eminent philosopher that America has produced, Professor Joseph Henry, who had then recently been appointed Secretary of the Smithsonian Institution. It thus happened that Espy compiled four successive official reports, accompanied by a long series of daily weather maps.

The next to prepare charts of the weather was Mr. James Glaisher of London, whose chart work began in 1848: it embraced only those British stations that could be reached by mail in twelve hours, but was kept up until the telegraph enabled him to compile a more complete series, day by day, during the London World's Fair in 1851, after which the work seems to have been given up in spite of his favorable recommendation. In 1861 and 1864, the United States Government published two large volumes, giving in detail all the observations received by the Smithsonian during the years 1854-59. This was after the death of Espy and the details thus published were more elaborate than could have been given on his ordinary daily weather charts. This work had been prepared under Professor Henry's direction, for the purpose of affording students the necessary data for a study of American storms. Much of it had been already shown upon the Daily Weather Map displayed at the Smithsonian building and made up from the daily weather reports received by telegraph. But it does not appear that any charts based upon this data were published until some were compiled by Professor I. A. Lapham, in 1869 at Milwaukee.

Meanwhile, synoptic weather maps had made great progress in Europe. Leverrier, in 1855, had begun the issue of daily bulletins which had rapidly grown into a national daily bulletin of weather telegrams.

Doubtless daily charts had been constructed by him in the beginning, but they were not published regularly until 1863, and after the bulletin had become "International." Since that date there has been a growing interest throughout the world in the subject of dynamic meteorology, and at the present time the necessary land and marine data exist, although not always easily accessible, for the construction of a daily synoptic map of one-half of the world.

The most important sets of daily weather maps are the daily charts of the International Bulletin at Paris; the tri-daily charts of the U. S. Signal Service and Weather Bureau; the international charts of the world, by Leverrier, and, especially, those of the bulletin of simultaneous observations published by the Signal Service; the daily charts for 1882-3 of the Atlantic Ocean, by the London Meteorological Office; the charts of the North Atlantic, by Hoffmeyer, and now by the coöperation of Denmark and Germany; the Australasian charts, by Wragge, and, especially, "The Monsoon Charts," by Eliot.

The Daily Map as at Present Constructed.

The actual synoptic daily maps now constructed throughout the world differ in some of the smaller details but agree in the broader features. Those for land areas are compiled daily from telegraphic reports, but those for the ocean areas must necessarily be compiled much later and, indeed, only as fast as the data can be received by mail. Both kinds almost invariably present atmospheric pressure by isobars, temperatures by isotherms, wind direction by an arrow pointing with the wind, the wind force either in miles per hour or by feathering the arrows for the figures 2, 4, 6, 8, 10, 12 on the Beaufort scale of wind force. The weather is shown by a circle, empty for clear and black for cloudy; the fact that it is raining or snowing is shown either by the letters R or S, or by the international symbols. In the maps now published by the U. S. Weather Bureau the whole area over which rain is reported to have fallen is shaded and the exact quantity of rain is given by figures for each station. In these maps also, the region within which temperature has risen or fallen 20° F. within twenty-four hours is shown by a line of heavy dots. Moreover, the path that has been followed by any center of low pres-

sure is shown by a line of heavy arrows. Other national maps give nearly the same data, with only such variations as respective local bureaus have found to be expedient: thus the daily map for India, and also that for the Indian monsoon region, is covered by short printed sentences stating that the temperature or pressure has risen or fallen, or that they are in excess or defect with reference to normal value.

In general it may be said that local conditions as to orography, and especially the general conditions depending upon latitude, suggest important modifications as to the data that should be shown upon the daily map; thus in India and equatorial regions the departure from the normal pressure, temperature and wind is apparently more helpful in weather predictions than the statement of the absolute pressure, temperature and wind which we prefer in the United States.

All these barometric pressures and, for that matter, the temperatures and the winds must be corrected for any local influences that may be supposed to effect their inter-comparability. Thus, pressure must be reduced to sea-level and must be expressed in some uniform, absolute standard; the former reduction is a rather arbitrary procedure, and so difficult is it to reduce the pressures at very high elevations to what they would be at sea-level that most of the national daily maps decline to make any effort to do this. The lower stations are reduced to sea-level, but upper stations, whose reduction would be uncertain by 1/10 of an inch, are either reduced to an upper level or published unreduced, so that the student can use them by considering their departures from normal values. With regard to the barometric standard, every effort has been made by the inter-comparison of barometers to bring all those of any one national system into harmony with each other, and, finally, to secure agreement between the standard or normal barometers preserved at the respective bureaus. The experience of the past twenty years has already shown that the mercurial barometer is more liable to have an appreciable error than was formerly suspected. Even the most expensive normals established at the International Bureau in Paris cannot be brought into perfect harmony. There is, therefore, in general, need of critical

examination. It is always understood that the barometric instrumental readings have been corrected for all instrumental and personal errors. By general consent, the mercurial barometer will, after the year 1899, be, by all observers, corrected for the influence of the variation of the force of gravity, a correction that has been recognized as important by high authorities, but whose application has been too long delayed. The aneroid barometer is not affected by the changes in the force of gravity.

The synoptic map just described is generally known as the Weather Map, but the observations of the clouds are by national services made with sufficient fullness to justify the preparation of a cloud map. Such a map has been compiled in manuscript, for the U. S. Weather Bureau, since July, 1871, but has never appeared as a published chart, although used daily in forecasting the weather.

It is often said that the United States is fortunate in having a broad expanse of country under one Government and one single telegraph system so that its daily weather map covers its whole area of three and a half million square miles, excluding only Alaska. But this broad expanse is happily enlarged by the addition of the Canadian reports on the north and the West Indian and Mexican reports on the south, which serve to double at least the area covered by our daily maps. In Europe, an area of four million square miles is covered; and in India and the Indian Ocean an area of six million square miles is also presented daily. Moreover, the outlying stations of Central and Western Asia already enable us to have a general idea of the atmospheric conditions over fully one-half of Asia. The southern portion of Africa is fairly represented on the daily map published by Cape Colony. The Australasian region is fairly represented by the great maps published by Wragge of Queensland. A daily map of the northern Atlantic is prepared and published by the *Deutsche Seewarte* and the Danish Government. The daily map of the whole northern hemisphere has been kept up by the U. S. Weather Bureau from 1875 to 1895, and was, in fact, published for about seven years.

The Daily Map for the Upper Air.

It will thus be seen that both national and international efforts are working steadily toward the preparation of daily weather maps for a

large portion of the globe. But these maps relate principally to the lower surface of the atmosphere. It would probably be exceedingly useful if we could have similar maps for some upper layer in the atmosphere; the difficulties of such work are, however, very great. It will require a hearty coöperation on the part of all engaged in mountain observations, balloon work, cloud studies and kite work. But as these branches of activity develop we may expect to see the daily map of the upper regions become more and more perfected. Efforts are sometimes made to reduce upward to the cloud level the temperatures and pressures observed at the surface of the ground. This can, however, only be done satisfactorily for maps of monthly and annual mean values. These are very useful for attaining a general idea of the so-called general circulation of the atmosphere, but their preparation involves hypotheses that still remain to be tested by actual experience.

There are very few weather bureaus that have not actively exerted themselves in one or more lines of work looking to the study of the atmosphere at heights as great as it is possible for us to attain. Among these lines of work we may enumerate the following:

1. From the earliest times much attention has been given to the kinds of clouds, their motions and the changes that take place. These have rarely, or perhaps never, been published in connection with the weather charts for the earth's surface, but manuscript charts of this kind have, since 1871, always been used in the daily work of the U. S. Weather Bureau, and cloud charts have also been published as special memoirs by several European students.

2. Permanent meteorological stations have been established upon many mountain tops, and their reports are nearly always included in the telegraphic work of the various national bureaus. Mount Washington and Pike's Peak have been two important American stations.

3. The exploration of the upper air by aeronauts in balloons has continued for a century past and, in fact, has given us our principal knowledge of the laws of diminution of temperature with altitude.

4. In order to attain still greater heights, meteorologists have in recent years utilized the so-called "sounding balloons," which ascend

without aeronauts but carry self-registering apparatus to the greatest heights that have yet been attained.

5. Kites were first used by Alexander Wilson in 1749 to carry self-registering thermometers up to the height of the lower clouds, but in recent years the apparatus has been so improved that the height of eleven thousand feet has already been attained at Blue Hill Observatory. The U. S. Weather Bureau hopes by flying kites simultaneously at many stations to compile an approximate map of the condition of the atmosphere over a large extent of country at an altitude of at least one mile.

As a result of these combined efforts, it is hoped that we shall attain an accurate knowledge of atmospheric conditions in the midst of the atmosphere.

The Weather Map for the Whole Globe.

In the present state of our knowledge, weather forecasts and seasonal predictions are made entirely by so-called empirical processes, that is to say, we utilize our experience as to the conditions that indicate the approach of a storm or a drought from a distance. We are not able to go back very far along the chain of causation and explain what has brought about these conditions; but finding them existant, as shown by our daily weather reports, we are able to say that, in all probability, they will continue to exist and move in certain directions for some time to come. They represent a combination of forces and a movement of masses so large that they can not easily be dissipated. Now the great desideratum is a better knowledge of the forces at work behind these phenomena; therefore, every weather bureau of any importance devotes a portion of its energies to the investigation of the physical and the mechanical processes that underlie all meteorological phenomena. However, the study of so-called theoretical meteorology makes exceedingly slow progress, partly because of the inherent difficulty of the subject, but equally because our statistical knowledge of the condition of the atmosphere is so exceedingly incomplete. In order to remedy the latter difficulty, Maury and his successors collected and tabulated a vast series of observations made by navigators of every race, but had only material

enough to compile satisfactory charts for those parts of the ocean that are most frequented by vessels. The Hydrographic Office of the U. S. Navy, the Admiralty Office of England and the Naval Offices of France and Russia, combined with the Merchant Marines of Holland, Denmark and Germany, have been most active in the study of ocean meteorology. But the study of storms and the larger meteorological phenomena cannot be thus divided between the landsmen and the navigators. It is a work in which both must coöperate if there is to be any successful result. In 1868, therefore, Leverrier began the publication of a general atlas or daily weather map for the whole globe. This was published on Mercator's projection and embraced, however, only the North Atlantic and the adjacent portions of America, Europe and Africa, viz. from longitude 105° west to 62° east of Paris, and from latitude 10° south to 70° north. The number of meteorological stations and ship reports was indeed too small to correctly represent the atmospheric conditions over this large area; but the charts were exceedingly suggestive and useful. After several years, this "*Atlas de Mouvements Généraux*" was discontinued, but the breadth of its design comported well with the comprehensive ideas of its author. No sooner had the Signal Office experienced, in 1871, the actual difficulties in the way of the prediction of American storms, than it was resolved that its work must be extended to the adjacent ocean and that it must embrace portions of both the Pacific and the Atlantic. The collection of data from ocean vessels began about July, 1871. This soon developed into an extensive marine division in the U. S. Signal Office. The vessels of the U. S. Navy soon began to contribute tri-daily simultaneous observations and, in 1873, General A. J. Myer successfully solicited the coöperation of all nations in the preparation of an international daily bulletin and map of the weather for 7:35 A. M. Washington mean time, or about 12:43 Greenwich mean time. This work was published from 1875 to 1884 as a daily bulletin and continued to 1889, in monthly summaries. The general results of ten years' work were published by General A. W. Greely in his annual report in 1893, with some additional tables and charts, as "Bulletin A." This "most gigantic, important

and successful undertaking in the history of meteorology" gave a first approximation to a daily weather map for 13 successive years for the whole northern hemisphere. As the present writer had much to do with the inception of this work and the proper publication of the data, it is not out of place for him to again express his conviction, as he did in 1871, that such work as this is the only conceivable basis for the proper study of the general meteorology of the globe and must always be recognized as the ultimate aim of the combined meteorological forces of the civilized nations of the globe. These bulletins and charts constitute to-day the great storehouse of data upon which to establish correct ideas as to the general motions of the atmosphere.

At present the *Deutsche Seewarte* at Hamburg, and the Danish Meteorological Office at Copenhagen, conjointly compile and publish a daily map of the North Atlantic and adjacent regions in continuation of the series begun by Hoffmeyer. The Meteorological Office at London, as its contribution to the international polar work of 1882-83, published a meteorological chart for the Atlantic Ocean daily for one year.

It may, therefore, be stated that one of the most important objects of a national weather service is to contribute its part towards the preparation of a daily weather map for the whole earth's surface as the proper basis for the study of dynamic meteorology.

Clouds and Cloud Charts.

On Plates XX-XXVI will be found representations of typical clouds as faithful as can be produced by modern chromo-lithographic processes. The study of the clouds has been insisted upon by the U. S. Weather Bureau since its beginning in 1870, and, as already stated, the details of cloud, as to kind, amount and direction, have been telegraphed and displayed upon manuscript charts ever since July, 1871, although the charts have not been printed for public use owing to the great expense of doing so. Without knowing much of the manner of formation of clouds, it has still been possible for mankind from the earliest days to observe their features and obtain early warnings of approaching storms and changes in the

Fig. 1.—CIRRO-CUMULUS CLOUDS.

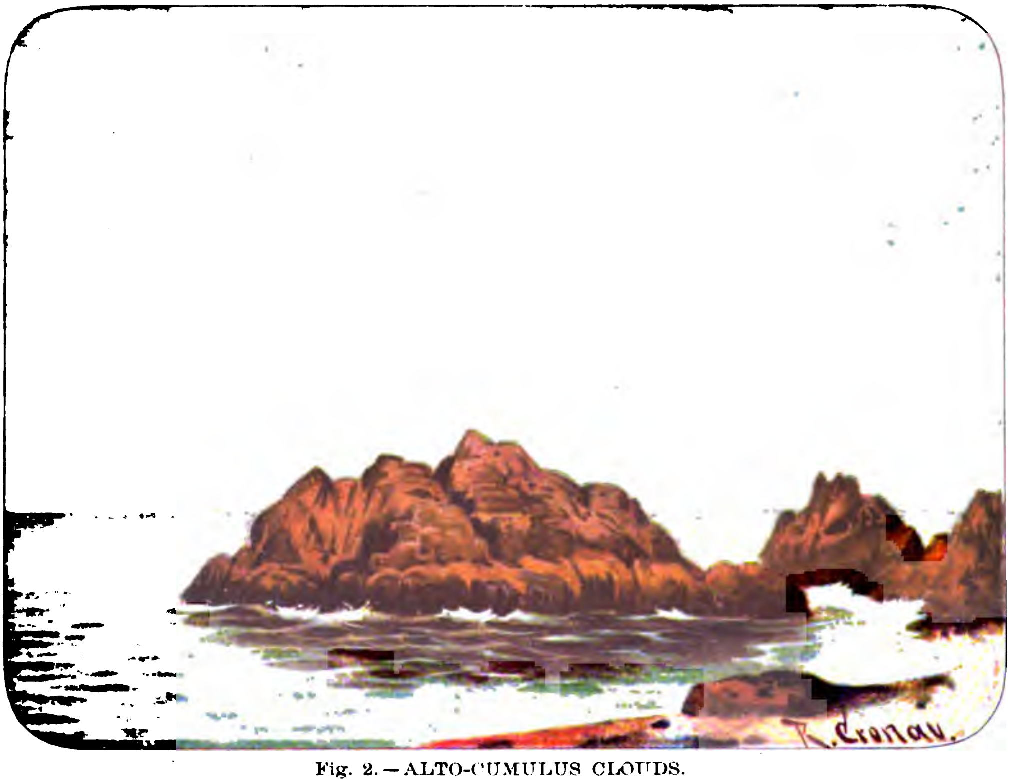

Fig. 2.—ALTO-CUMULUS CLOUDS.

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weather. The systematic utilization of such cloud study on a large scale demands, first of all, a proper nomenclature. This was supplied by Luke Howard in the early part of the present century, and the terms introduced by him still remain in use, although it may be with slightly different significations. At the present time the meteorological world is agreed as to the adoption of the terms and definitions recommended by the International Meteorological Committee in 1896, as follows:

1. Cirrus (Ci.).—Individual delicate clouds, or detached clouds of a delicate and fibrous appearance, frequently taking the form of feathers, generally of a white color, sometimes in belts that converge by perspective; the average altitude is between 8,000 and 10,000 meters.

2. Cirro-stratus (Ci-s.).—A thin whitish sheet sometimes completely covering the sky; often producing halos around the sun and moon.

3. Cirro-cumulus (Ci-cu.).—Small globular masses, or white flakes having slight shadows or none, arranged in groups and often in ranks and files.

4. Alto-cumulus (A-cu.).—Rather large globular masses, white or greyish tint, partially shaded, arranged in groups or lines.

5. Alto-stratus (A-s.).—A thick sheet of a grey or bluish color, showing a brilliant patch in the neighborhood of the sun or moon; may give rise to coronæ without halos.

6. Strato-cumulus (S-cu.).—Large globular masses or rolls of dark cloud, frequently covering the whole sky, especially in winter, and sometimes giving it a wavy appearance; patches of blue sky may be visible through it.

7. Nimbus (N.).—A thick layer of dark clouds without shape and with ragged edges from which continued rain or snow falls or has fallen.

8. Cumulus (Cu.).—Thick clouds of which the upper surface is dome-shaped and shows protuberances, while the surface of the base is horizontal; the true cumulus has well-defined upper and lower limits.

9. Cumulo-nimbus (Cu-n.).—Heavy masses of clouds rising like mountains, turrets or anvils, having generally a sheet or screen extending from the top called "false cirrus" and at the base a mass of clouds similar to nimbus; from the base local showers of rain, snow or hail appear to fall.

10. Stratus (S.).—A horizontal sheet of lifted fog; when this sheet is broken up into irregular shreds by the wind or by the summits of mountains, it may be designated as "fracto-stratus."

The following additional names and combinations are allowable:

11. Fracto-nimbus.—A layer of nimbus broken up into shreds as if by the wind or small loose clouds floating at a low level underneath a large nimbus; equivalent to the "scud" of English sailors.

12. Fracto-cumulus.—Small clouds attending the lower edge of the cumulus and appearing as if torn from it by the wind, but in reality often formed in wind currents blowing toward the cumulo-nimbus.

13. False cirrus.—A sheet similar to cirrus extending out from the top of a cumulus cloud, sometimes known as an "overflow cloud."

14. Fracto-stratus (see stratus).

15. Strati-formis } Terms applied to clouds that resemble the stratus or
16. Cumuli-formis } the cumulus.

17. Mammato-cumulus.—A cumulus whose lower surface is not smooth, but has a mammillated appearance.

In observing clouds the record should at least show the kind, the amount of sky covered by each variety, and the direction from which each layer is apparently moving. The exact height of the cloud and the velocity in miles per hour is determined by the proper use of the nephoscope or the more elaborate photogrammeter. Observers who cannot undertake these elaborate measurements are, however, requested to make a careful study of the changes going on in the clouds, viz., whether they are apparently rising or falling, dissipating or thickening. If clouds are arranged in waves or belts that converge towards the horizon, or in symmetrical rank and file, these and other peculiarities should be noticed in full detail.

A full description of all the forms of clouds that have been described since the publication of Howard's system is given by Mr. H. H. Clayton in one of the memoirs of Blue Hill Observatory, accompanied by some suggestions as to mode of formation and their relation to the movements of the atmosphere.

Cloud phenomena offer a field for study and experiment that is of great importance and has only lately begun to be appreciated. The works of Coulier, Mascart, Aitken, Kiesling, Robert von Helmholtz, Carl Barus, and C. T. R. Wilson of Cambridge have given us the first idea of the process of cloudy condensation by which the minutest cloud particles are formed. Physicists need now to follow up the process and determine the ordinary methods by which large raindrops are formed. As to this important step, several important hypotheses have already been suggested:

1. That the larger particles falling faster than the small ones overtake them and swallow them up;

2. That the small particles are attracted together electrically;

3. That the upper particles of a cloud may be cooled by radiation and, therefore, grow larger by the condensation of surrounding vapor;

4. That the rapid currents of air within a cloud give the larger particles a momentum that carries them forward among the smaller ones so that they grow by accretion;

5. That cloudy air or dustless air by further expansion and cooling may become supersaturated up to a certain limit when a large mass of vapor will suddenly condense into a big drop, involving also the smaller particles within that space; this latter process may involve an electric discharge of great intensity when the drops are large, but of feeble intensity when they are small.

The thermodynamics and hydrodynamics involved in the formation of clouds form a comparatively difficult study that has been successfully attacked by Hertz, von Bezold and Helmholtz, whose papers are translated in my "Mechanics of the Earth's Atmosphere." The special application of their studies has been elaborated by Prof. Marcel Brillouin in a memoir published in 1898, a preliminary account of which is published in the Monthly Weather Review for October, 1897.

Special Observations and Investigations.

While the national bureaus collect data for the study of the atmosphere, they have it in their power to make daily applications of the useful knowledge thus acquired. Those bureaus that cover a large area are generally able to make rational predictions as to the probable weather of the coming twenty-four hours and, especially, to foresee the development and approach of severe storms. This is considered to be a primary duty to the public, since in this way they can render an immediate return for the money spent in the study of the atmosphere. In some bureaus the attention given to practical applications may seem to be too large in proportion to the needs of the fundamental study of the atmosphere. But this is probably an unjust criticism. Theoretical meteorology is not yet the predominating feature in the science. Our progress in unraveling the difficulties of meteorological problems is necessarily so slow and so dependent upon the general progress of mathematical physics that we may compare theoretical meteorology to the slow-growing pines, beeches and oaks of the forest which, when young, are protected by the rapid-growing

and short-lived trees but become the masters of the forest when the latter have died away.

While, therefore, keeping alive the study of theoretical meteorology, most of the national weather bureaus have developed appropriate lines of useful work in addition to the daily storm and weather predictions already mentioned. Among these we may enumerate the following:

1. The continuous record of all features of the weather is kept as an official record for use in the courts of law, especially a record of the high winds that can produce damage or destruction of property; a record of heavy rains within short periods of time, such as produce destructive floods in cities and rivers; a record of general rains, on which the general regimen of the rivers depends.

2. A record of every climatic feature that is supposed to affect local agriculture, especially frosts, droughts, maximum and minimum temperatures, rainfall and sunshine, depth of snow and evaporation.

3. A record of the heights of rivers for the prediction of rising and falling water, and the study of erosion.

4. A record of the amount of sunshine and cloudiness in its bearing on the growth and health of animals and plants

5. A record of the temperature of the soil at different depths for agricultural studies and at great depths for geological studies.

6. A record of the amount of evaporation from the surface of fresh water and its bearing upon the storage of water for irrigation.

7. The record of thunderstorms and of damage by lightning, hail and wind gusts.

8. Observations on terrestrial magnetism, especially in case that this is not otherwise provided for by some other office or bureau of the respective governments. This record is not kept because any very important relation has yet been shown to exist between meteorology and terrestrial magnetism; but there is a widespread belief that intimate relations of this character do exist and that the two subjects must be considered as cognate branches of terrestrial physics. Continuous photographic records of the movements of the magnetic needle and of earth currents are kept for comparison with other phenomena, astronomical or terrestrial.

9. Earthquakes and seismic phenomena belong to geology, but in the absence of systematic attention to the subject by other bureaus, the meteorological records are often the principal source from which observations are drawn. It is also recognized that occasionally earthquakes and volcanic eruptions may be determined by meteorological conditions. In general, both earthquakes and oceanic tides and a certain class of atmospheric phenomena may be simply different manifestations of the tidal forces of the sun and moon and it is appropriate that the meteorologist should join with other students of terrestrial physics in contributing to elucidate the phenomena.

10. The registration of tides in the ocean and fluctuations in the levels of the lakes with a study of these so far as they are affected by atmospheric changes.

11. The climatic conditions that affect health, disease and death for the students of hygiene.

12. The observation of the dust in the atmosphere, both as to its quantity and character and a study of its relations to disease, organic life, the production of fog and rain and the radiation of heat and other phenomena.

13. The registration and study of atmospheric electricity and the elucidation of its origin and function in meteorology.

14. The observation of ozone, carbonic acid gas, ammonia, aqueous vapor and other chemicals dispersed in small quantities through the otherwise pure air and the study of their diverse influences on rock weathering, on animal and vegetable life.

15. Optical phenomena, such as the blueness of the sky and its relation to photographic effects, and its dependence upon the free moisture in the air: The polarization of sky light and its dependence on the moisture: Solar and lunar halos and coronæ, their dependence upon moisture and their relation to storms.

16. The study of the clouds, their structure and method of formation; their altitude and motions.

17. Observations of evaporation and its relation to irrigation, water-storage and the growth of plants.

18. The depth of frost in the ground and its relation to the foundations of roads and buildings.

19. The relation between rainfall and evaporation on the one hand, and the quantity of water flowing in the rivers on the other.

20. The formation of frost-work at the surface of the ground and its relation to the soil beneath.

21. The formation of sleet or ice on the branches and leaves of trees and plants or on telegraph wires, and the injury done thereby to agriculture and business.

22. The record of the flow of water from springs, the flow of underground water, the temperature of spring water, all in relation to the water supply.

23. The comparison and standardization of meteorological instruments and apparatus, especially of the thermometers, barometers, anemometers, rain-gauges, sunshine recorders, actinometers, sextants and other apparatus used by explorers who keep meteorological records; the improvement and invention of self-registering apparatus.

24. The study of atmospheric absorption of solar energy by means of thermal, optical and chemical methods.

25. The study of the radiation of heat by the earth and air, the clouds and the invisible vapor.

26. The resistance to the motion of the air when opposed by various obstacles, or the effect of the wind on sails and buildings.

27. A record of the phenomena of the aurora and the study of its connection with magnetic disturbances and natural electric currents on telegraph wires and with the condition of the atmosphere as to wind and moisture.

28. Records of the audibility of sound and the visibility of signals in fogs, for use in marine signalling.

29. The education of the public and the dissipation of popular errors by teaching, lecturing and popular writings.

The Distribution of Information.

But while such a national weather bureau thus labors to complete its records and maps, it must also, with equal assiduity distribute the information thus attained. In this branch of work there are very great differences of practice in different bureaus. With but few exceptions, however, each central office publishes some form of daily

weather map and accompanying bulletin and distributes these to the community in such manner that all who are especially interested may promptly acquaint themselves with the conditions then existing and the probabilities of the future. The daily examination of the U. S. Weather Map by the public has always proved to be of the greatest assistance in educating it out of the erroneous ideas about the weather which were instilled into all of us as children. This educational influence has been an essential feature of the pioneer work in meteorology in every nation during the past thirty years. The wide distribution of the Weather Map has been absolutely necessary in order to convince the public that weather changes go on in obedience to natural laws and that there is no chance or astrology about it. Thus the way has been paved for the introduction of the study of meteorology into the universities. Nearly every national weather bureau has, therefore, a more or less intimate affiliation with courses of instruction in the universities.

The state services must coöperate with the larger weather bureaus in the work of the distribution of forecasts and warnings by telegraph, telephone, postal cards and signals. Although much of this work is done by the Federal Government, yet there are always left fields of usefulness in which the state service may gain distinction. In Ohio, Professor Mendenhall conceived of the system of railroad train signals as a means of bringing the forecasts directly to the vision of the farmers along the route. In Georgia, Professor Mell introduced a very widespread system of special flag signals. In Chicago, Professor Moore experimented with the search-light as a means of signalling. In some places it may be practicable to use a cannon or steam whistle as a means of signalling for short distances. On the seacoast, where fog-horns are available, they have been used with success in signalling for distances of five miles. But, in general, the flag signal used by the U. S. Weather Bureau, or the ball signals devised at Orono, Maine, or the cone and cylinder signals used in the European services, are the best supplements to the special telegraph and telephone messages.

Next after the distribution of daily forecasts through the morning

and evening press, through the telegraphic bulletins, and, especially, through the postal card system, the most popular method consists in the display of flag signals. These flags are illustrated on Plate XXVI and may be classified as temperature signals, wind signals and weather signals. The wind signals, as will be seen from the plate, indicate the direction from which the wind is expected, and, in the case of dangerous winds, they show whether a storm or a hurricane is at hand.

The temperature signals show merely whether the temperature will rise or fall within the next twenty-four hours, but are only displayed when the change of temperature is expected to be quite decided. For changes of a few degrees only, no signal is shown, and this is called *stationary temperature.*

Special signals are displayed for cold waves, which words combine both the ideas of low temperature and strong wind.

The weather signals show whether the next twenty-four hours may be expected to be *fair*, namely, without rain; *showery*, namely, with short or light rains; or *rainy* or *snowy*. These general indications of the approaching weather answer the needs of a large constituency. Those who, like the farmers and sailors, are accustomed to study the sky very closely, generally find great help from these weather signals. To those whose important business demands special attention, special weather forecasts are sent on request by telegraph and telephone.

In addition to the daily storm and weather predictions and signals which are only practicable on land, the navigator who is far from shore must be provided with such charts and rules as will best enable him to avoid storms and secure favorable winds. To this end the various national hydrographic offices and the marine meteorologists occupy themselves with the preparation and distribution of charts showing the average condition within each small square over the surface of the ocean. These charts give normal data for the ocean bearing on winds and storms, ocean currents, temperatures, density and color of ocean water, the paths of storm centres and the frequency of dangerous winds and of calms. These volumes of charts are usually accompanied by elaborate sailing directions. Ocean

meteorology is attended to by the naval or the marine hydrographic offices. The U. S. Hydrographic Office has, however, introduced the custom of publishing current monthly charts known as the "Pilot Chart of the North Atlantic" and the "Pilot Chart of the North Pacific" respectively; these give not only the normal values for each month, but the actual values for the preceding month of the current year, so that the navigator may perceive whether any general departures from normal values prevail at the present time. This has been called a forecast for the coming month, but is more properly in the nature of a suggestion as to what may possibly occur, since the normal values rarely ever represent any specific date or condition. The marine charts include full magnetic data for the use of the navigator, wherefore meteorological stations find therein an added reason for including magnetism in their schedule of work.

The Prediction of General Storms and Hurricanes.

The accompanying charts, Figures Nos. 21-26 inclusive, show the general conditions attending the severe storm of November 26 and 27, 1898, off the New England coast. This storm is of a type that has usually been considered difficult to predict. From the first chart the reader will perceive that at 8 A. M., November 26, an area of low pressure (29.90 inches), with its attendant circulation of winds, was central in northwestern Ohio. The second chart shows that within four hours after that, viz., at noon, a new storm centre had appeared off the coast of North Carolina, and the third chart shows that three hours later the former centre had disappeared and a new one was rapidly developing. Cases similar to this have frequently been recorded. In general, the storm centre is said to jump across the Appalachians by the formation of a new centre on the ocean side or southeast of these mountains. The process has been fully described on pages 141-146 of my "Preparatory Studies." When the precipitation falls as snow rather than rain, the winds are more violent, the barometer sinks lower at the centre and the storm as a whole is said to have greater energy. Of course this occurs only when the clear, dry air on the western side of the storm centre is cold enough to produce snow in its conflict and mixture with the warm, moist air

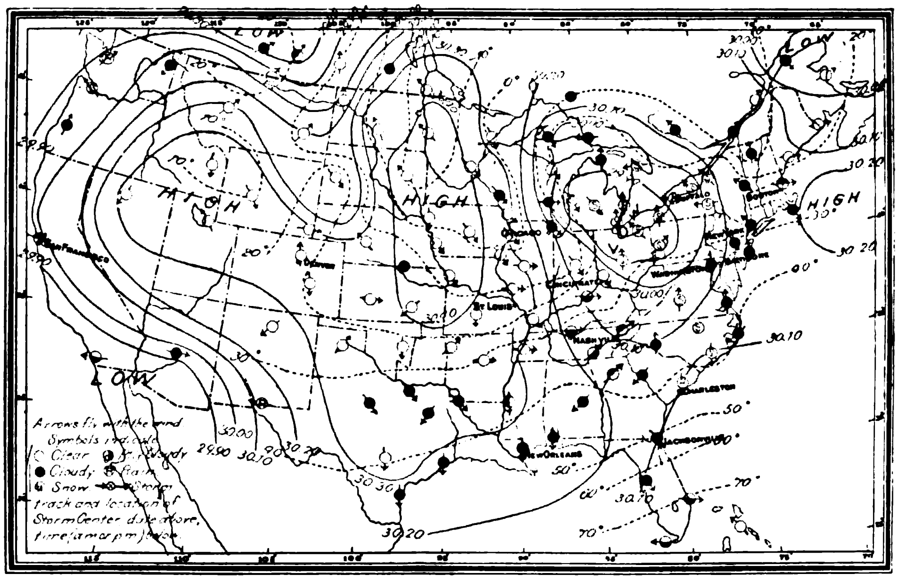

FIG. 21.—Storm of November 26, 1898, 8 A. M.

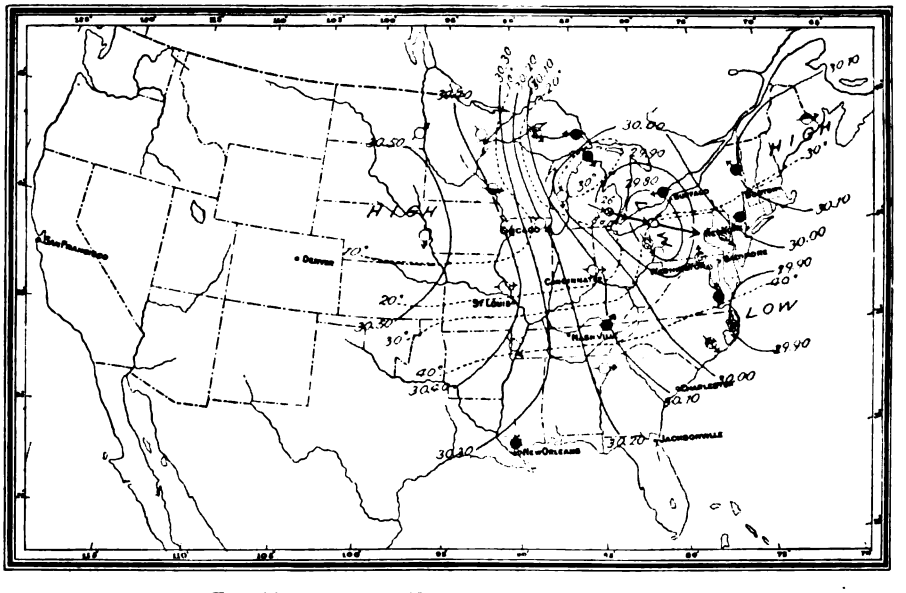

FIG. 22.—Storm of November 26, 1898, 12 noon.

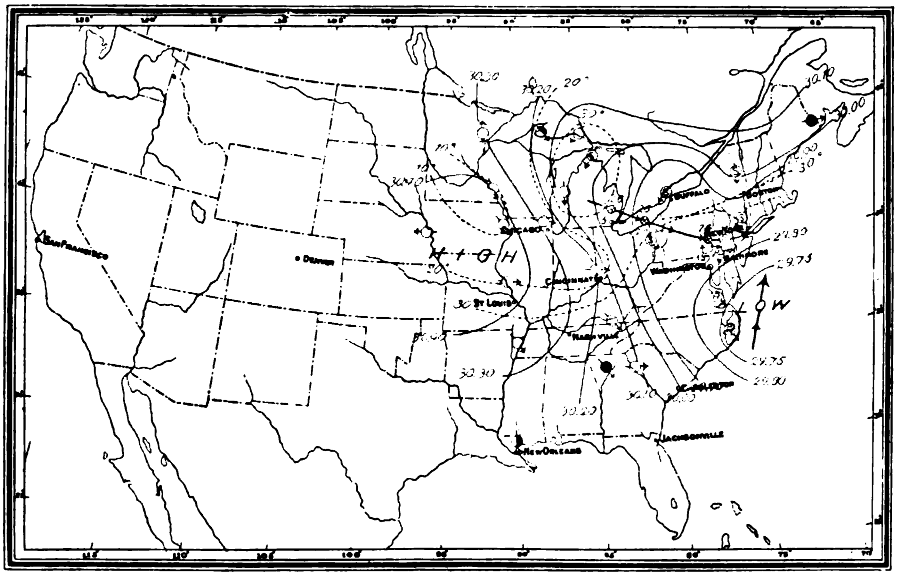

Fig. 23.—Storm of November 26, 1898, 3 P. M.

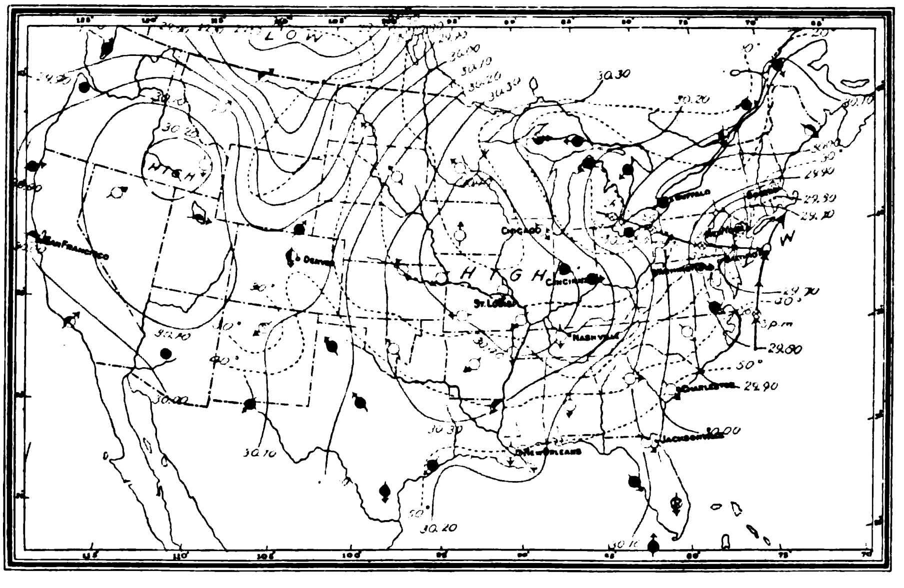

Fig. 24.—Storm of November 26, 1898, 8 P. M.

that flows westward over the Atlantic coast states from the ocean and even from the Gulf Stream on the east.

The maps, Figures Nos. 23-26, show the paths of two storm centres apparently running into each other at 8 P. M. of the 26th, but according to the views just expressed, it would be more proper to represent the path of the first storm as dying out after 3 P. M. of the 26th, while the new centre, which had begun to form off the coast of North Carolina very early in the morning, had by noon become well developed, and, thereafter, pursued its own regular path.

Although in general, storms of this type move eastward with much regularity across the United States, and although the new storm centre forming off the coast of North Carolina undoubtedly belongs to the class that pursues a northeasterly path toward Nova Scotia, yet in the actual work of forecasting it is not safe to rely entirely upon these general characteristics alone. Changes in the direction of movement of individual storms are not rare, and a series of storms will sometimes pursue one type of path week after week. Every one has observed how apt we are to have several rainy Sundays after a first one has occurred. This is due to the fact that a series of storm centres is following one after the other in regular succession, and the series of rainy Sundays is not broken up until this series has died out and another series along another type of paths has appeared. In the present case the predictions made at 8 A. M. November 26 were based upon the study of the charts of November 24, 25 and 26. This particular storm centre made a sudden large movement southward between the 25th at 8 P. M. and the 26th at 8 A. M. It was therefore not unreasonable to assume that its tendency would be to continue southward or southeastward during the next twelve hours. On the other hand, the winds with rain or snow on the coast at 8 A. M. showed that conditions were favorable for the evolution of a large amount of latent heat which would either feed the original cyclonic whirl or produce a special indraught and a new whirl on the Atlantic coast. That the latter would be the case was evident from the north winds at Wilmington and Charleston, S. C., and northeast wind at Hatteras.

The anticipations of the forecaster were abundantly verified. Perceiving the threatening condition of affairs, he not only ordered northeast storm signals along the New England coast from Newport to Eastport, but also southeast storm signals from Montauk Point south to Norfolk, with additional warnings of snow and rain. Foreseeing that the northwest winds which follow a storm centre would form a severe cold wave with snow over the Lower Lakes, he sent appropriate warnings to that region also. At the same time the railroad companies of the Atlantic States were notified of the approaching heavy snow. During the evening of Saturday the 26th and the early morning of Sunday the 27th, maximum wind velocities of 50 and 60 miles per hour were reported from the whole New England and Middle Atlantic coast. The centre of lowest pressure moved over Cape Cod and, at 8 A. M. November 27, was central perhaps 50 miles east of Boston. The oldest residents of Cape Cod report that no storm so severe as this had ever before been experienced there. It was during this night that the steamer Portland, bound from Boston to Portland, Me., was lost with all on board.

While the storm centre was moving northeastward during the night of the 26th-27th, the great area of high pressure and cold weather west of the Appalachians moved southward, bringing freezing weather to the Gulf and South Atlantic States and frost in northern Florida on the morning of November 27. Full and ample warning of the latter was telegraphed to the districts that were menaced, although the low temperatures did not last long enough to do any great amount of injury. This illustrates the general principle that the heavy wind and snowstorms of winter occur when an area of decidedly high pressure and very cold air exists immediately to the westward. From a mechanical point of view, we know that this mass of cold, dry air is being driven toward the equator by the centrifugal force of the rapidly-revolving earth and pushes southward with more force than the same volume of warm, moist air. Just as a mass of cold air descends to the floor of a room and raises a similar volume of the warm air at the floor to the upper part of the room, all owing to the differential action of the force of gravity on cold and warm air

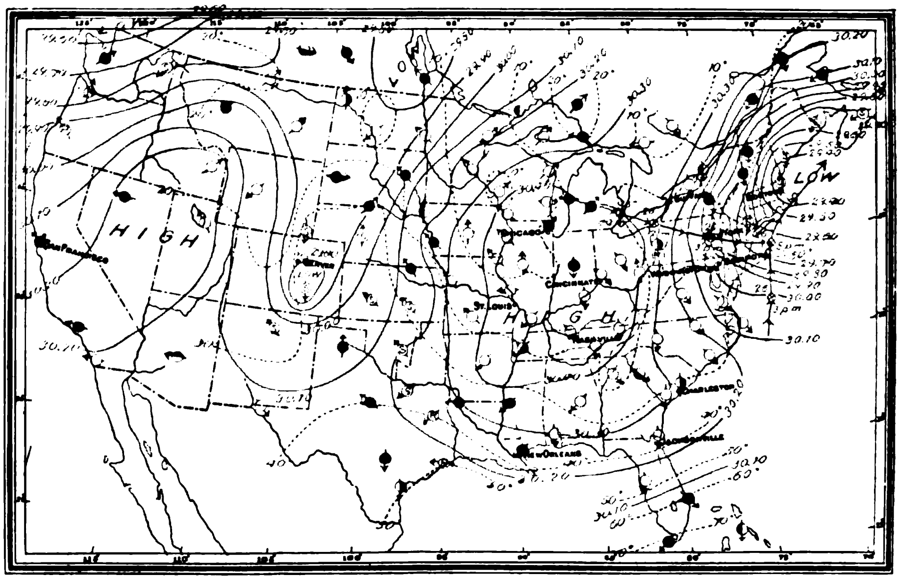

FIG. 25.—Storm of November 27, 1898, 8 A. M.

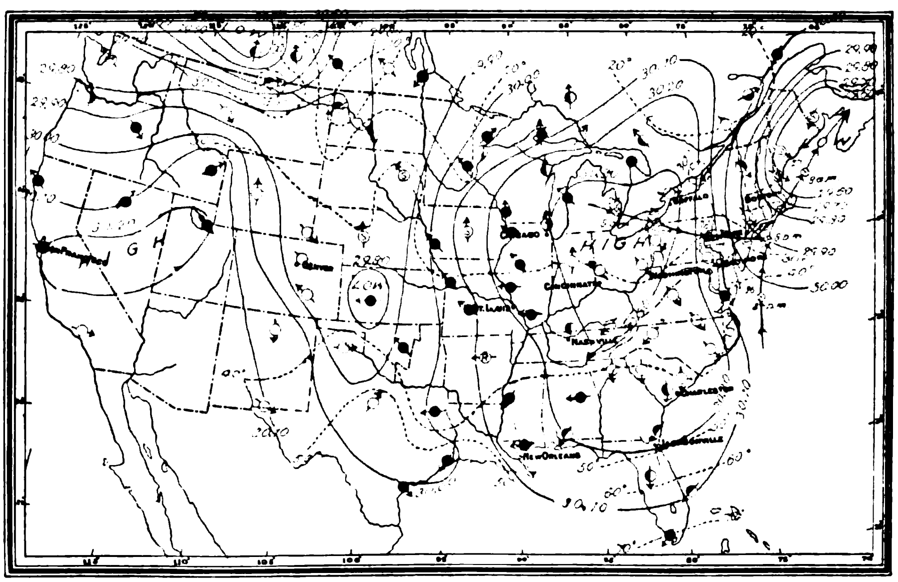

FIG. 26.—Storm of November 27, 1898, 8 P. M.

respectively, just so the differential action of the centrifugal force on masses of warm and cold air sends them respectively toward the pole and the equator. The process is precisely the same as that which takes place in the so-called Babcock separator, well known to every dairyman. In this ingenious apparatus the centrifugal force of the rapidly-revolving particles of heavy water drive them away from the axis of rotation more forcibly than the lighter particles of cream are driven, thus giving the mechanism a chance to separate one from the other. Ordinarily, when a body falls through a small distance at the earth's surface, the force of gravity can act upon it only for a few seconds; but gravitation being a very great force can in a few seconds give the body a very great velocity. Now the weak centrifugal force of the diurnal rotation may continue steadily, acting for an indefinitely long time and be thus enabled to coöperate with gravity and assist in giving the masses of cold, dry air the very great velocities of 30, 40 and 50 miles per hour which are observed in the northers from Manitoba to the Gulf of Mexico. It thus happens that the blizzards and cold waves of our northern states become the northers of the Gulf of Mexico and the Caribbean Sea.

The principal paths pursued by storm centres, as shown by the experience of the past forty years, are summarized in two U. S. Weather Bureau publications, viz., Bulletin A and Bulletin 20, to which the reader may refer for numerous details. A few of the more important types influencing Maryland are given in the portion by Mr. Walz.

In general, although the forecaster knows the various types of paths that storms have taken when passing through any given region, yet in making specific forecasts he always waits a few hours until he has observed the path of any particular storm long enough to know along which of these tracks and at what speed the present storm is travelling.

The hurricane is a whirlwind that starts in the tropical regions a little way north or south of the equator. Our North Atlantic hurricanes, after moving toward the westnorthwest for several days, turn northward and conclude by moving northeastward for several days

longer until the whirl is broken up. They may thus last for one, two, or three weeks, and their centres describe a path of from 3,000 to 6,000 miles in length. Their movements are so steady that when once the presence of a hurricane is clearly established, the prediction of its path is comparatively simple. The West Indian hurricanes may pass either through the Caribbean Sea into the Gulf of Mexico and thence northward over Texas to the Lake region, or they may skirt the northern edge of the West Indies and strike the coast of America near Cape Hatteras and move thence northeast past Newfoundland. Similar hurricanes starting further east or turning sooner northward may pass close to Bermuda or even over the Azores. When the path of the centre of a hurricane is foreseen, the prediction of wind and weather for any locality depends simply upon the fact that the meteorological elements are disposed quite symmetrically about the centre of the whirling system of winds and move along with it, slowly enlarging the area over which they extend. The maximum dimensions of the hurricane are generally attained when its centre has reached latitude 40° or 50° north.

The Prediction of Rain.

According to theoretical physics, rain can be produced only by the cooling of the air and its contained moisture below the dew-point. With this principle in view, the first weather maps were scanned in order to locate the regions where the dew-point of the air at the surface of the ground was very near to the actual temperature of the air. Such moist air as this should ascend, cool by expansion and deposit some of its moisture as cloud or rain. But it was soon found that the rain areas on the U. S. Weather Map do not correspond closely to these regions where the dew-point at the ground is but little below the air temperature. Another theory, that of Dalton, that rain is due to mixtures of cold and warm air was long discredited, but its exact importance has recently been evaluated by Brillouin. The exact method of formation of rain and the conditions essential thereto are not yet satisfactorily established. It has been shown that the dust floating in the air forms the nuclei for the first formation of cloud particles; but how these are brought together into raindrops is not

Fig. 1.—ALTO-STRATUS WITH FRACTO-NIMBUS CLOUDS.

Fig. 2.—STRATO-CUMULUS CLOUDS.

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so clear. There is apparently a state of supersaturation in air free from dust which may also exist in those portions of the cloud from which rain falls, as well as when rain falls from a sky without clouds. It has, therefore, been long since conceded that the prediction of rain cannot safely be made to depend upon any process of reasoning upon these obscure physical conditions; ascending currents of moist air of considerable strength are undoubtedly one essential; but even though the Weather Map shows that these are present, yet we have no means of deciding whether rain will follow except by analogy and experience, and it is only when the rainfall is actually observed that it is considered safe to say that conditions are favorable for rain in the future in the region over which the wind will carry these rain-bearing clouds. Some of the temperature conditions essential to rain have been quite clearly defined by von Bezold, and, lately, by Brillouin, but it is not certain that these are the only conditions, nor is it always possible, by means of observations in the lower stratum, to tell whether these conditions are fulfilled anywhere above us. After an interval of dry weather the conditions that imply rain are particularly disappointing, and all experience shows that we have not yet learned enough about the subject to justify predictions based on general theory. Therefore, in general, no matter how favorable the winds and moisture may seem to be, it is best not to predict rain until we have actually seen it fall at some earlier point in the course of the storm.

The Prediction of Wind.

The relation between the wind and the isobars was long considered fairly definite. Brandes, in 1820, showed that the winds incline inwards to the isobars. Buys-Ballot, in 1867, predicted the winds for Holland for twenty-four hours in advance, according to his general rule that an isabnormal line, or one joining two stations at which the barometer stands equally far below the normal values, is perpendicular to the direction of the wind that will prevail on the following day. As soon as comprehensive daily weather maps were available it was perceived by Redfield and Reid that the winds circulate about centres of low pressure in such a way that they do not follow the isobars precisely, but are inclined inward at a considerable

angle, depending on the latitude of a place and the character of the distribution of pressure. This system of isobars and winds moves along as a whole over the earth's surface. It generally requires several days to develop its most perfect symmetry, and, again, several other days before the whole cyclonic system is broken up and a new eddy is formed. The general path of any such cyclonic system as a whole is shown by watching the successive daily weather maps and the study of such paths for many years has shown their movements to be subject to laws that will eventually be clearly defined. Their movements apparently depend upon several conspiring influences. In small cyclones the general currents of air in the northern hemisphere bring in, on the western side, cold, dry air; but, on the eastern side, warm, moist air. The progress of the whirl as a whole is toward the moister side, and, to a certain extent, toward the rainy side; perhaps, more properly speaking, toward the side where the cloudy precipitation predominates, rather than toward the rainy side as such. But the irregularities in the movements, due to causes that are beyond our ken, forbid any attempt to predict winds for a specific place and date upon any such general basis. The practice of the forecaster consists in combining with his general knowledge of the storm tracks a specific study of the track immediately under consideration. For instance, he plots upon a morning map not only the centre of the system of isobars and winds for that morning, but also the locations of the centres for several days past, and thus ascertains the specific peculiarities of the storm under consideration. Upon this basis he predicts where the centre will be twenty-four hours hence, and, with it, the system of circulating winds, whence he is able to forecast the wind for any particular portion of the country. Local experience has generally confirmed the rule that if the direction and force of the wind is known, then all the other features of the weather may be inferred. In fact, a table or diagram called a "wind-rose" may be made out showing what weather attends or follows each given direction of the wind for rising and falling barometers, and predictions made according to such a table will be verified, at least, three times out of four.

Prediction of a Frost or Freeze.

The fact that frosts frequently occur on clear nights, but not invariably so, has led to investigations which show that their occurrence depends quite as much upon the moisture in the air as it does upon the clearness of the sky. A clear sky allows the soil and plants to radiate their internal heat, and their surfaces soon cool down to such a low temperature that dew or frost begins to be deposited upon them. Now it is not the mere deposit of frost that injures the plant, but it is the low temperature to which the plant cools by radiation which has, on the one hand, caused the frost to be formed on the outside of the plant, and, on the other hand, has seriously damaged it internally. When the leaf surface has cooled down to the temperature at which dew is deposited that very process of deposition causes a large amount of heat, the latent heat of vaporization, to be given up to the air, and this heat must be lost by convection or radiation before any more dew can be deposited; therefore, the whole process of cooling is retarded so long as dew is being deposited; and the same is still more true of the formation of frost.

The average dew-point of the free air changes much more slowly from hour to hour than does the temperature of the air. It generally rises slightly during the day-time because of the evaporation of moisture from land and water. It falls a little in the night-time because of the condensation of atmospheric vapor into dew or frost. We shall not go far wrong if we assume that the dew-point observed at 8 A. M. of one day will be the same at 8 A. M. the next unless there has, in the mean time, been an entire change in the atmosphere due to the inflow of air from a distance. If the dew-point is decidedly above freezing on any morning, we may, therefore, hazard the prediction that no frost will occur during the ensuing twenty-four hours, but more certainty is attained by determining the dew-point at sunset or at 8 P. M., and arguing thence as to the frost during that night. This has been the ordinary method of predicting frosts by those who have not access to the U. S. Daily Weather Map. The latter enables one to form some idea as to whether the cold air is approaching from a distance, and, therefore, greatly increases the

accuracy of the frost predictions. The former method will achieve 50 per cent of verification in countries like Europe that are not subject to the sudden irruptions of cold air in the rear of rapidly moving areas of low pressure, but would be far less useful in the United States. On the American continent dry air whose dew-point is below freezing is quite commonly drawn into circulation around the low area, and the frost prediction for any region must depend almost entirely upon our knowledge of the dew-point and of the clearness of the sky peculiar to the air that is about to flow over that spot.

Very often this inflowing air is so cold and dry that plants are frozen without any deposition of frost; that is to say, the dew-point is far below the freezing temperature. These are called freezes or dry freezes as distinguished from frosts. The prediction of a freeze depends more upon the proper estimate of the temperature than of the dew-point, provided only that the latter be far below the temperature. Frosts are prevented by the formation of a layer of clouds, but freezes are only slightly affected by such protection from radiation of heat.

Prediction of Cold Waves and Blizzards.

This class of storms is very severely felt in North America. Undoubtedly something of the same kind must exist in China and eastern Asia; the blizzard is apparently equivalent to the *buran* of Russia and Siberia; a milder storm of the same class is known as the *pampero* in South America; the *northers* of the Gulf of Mexico and the Caribbean Sea are the southern extensions of the blizzards of the Missouri and Mississippi valleys. In the United States, areas of low pressure have strong, cool, dry northwest winds on their north and west sides, but warm, moist south and west winds on the south and east sides. The air of the northwest winds, on account of its density, remains near the ground and lifts up the lighter warm, moist strata of the southwest winds, and in doing so produces rain or snow over an area which may be defined as the area between cloudy, cold northwest winds and warm, moist, cloudy or rainy southwest winds. This area is, in fact, a region of mixture west of the region of ascending air; it may be from 50 to 300 miles broad and

1,000 miles long. In crossing from the east side to the west side of this area we experience a very rapid decrease of temperature and increase of pressure and a series of violent gusts of wind with snow. This is the region of the blizzard. If the winds are less violent and the snow less troublesome, we have the modification known simply as the cold wave. This region, or belt, of violent winds and strongly contrasted temperatures advances southward and eastward in the rear of an area of low pressure with great regularity. Several successive daily weather maps will show the rate of progress of the front of the blizzard, or cold wave; but the rate will be found to vary with every individual storm. Probably this rate and the other peculiarities of the blizzards and cold waves depend largely upon the rate of movement of the upper strata of air as also upon the relative density at the surface of the ground of the opposing warm and cold airs, but as yet no law or rule has been formulated connecting these rates of motion with the ultimate causes. It is the custom for the forecaster to proceed empirically step by step, from day to day, issuing his forewarnings of cold waves for one or two days in advance, according as the cold area seems to be spreading, more or less rapidly, in one direction or another.

Prediction of Hot Waves, Chinooks and Foehns.

When a mass of air descends rapidly from a considerable height down to the earth's surface it is compressed by reason of the greater pressure of the air above it, and, therefore, warmed so that it may appear to a local observer abnormally warm and dry. This is especially true if, before its descent, the air had been pushed up over some high land or cold air and deposited a portion of its vapor as rain, leaving the remaining air warmer than is consistent with the ordinary equilibrium of the atmosphere. The descending air probably loses by the evaporation of moisture and by radiation a portion of the temperature produced by its compression, but it remains true that, as a general rule, rapidly-descending air is unusually warm when it reaches the earth's surface. This constitutes the *foehn* wind of Switzerland, or the dry chinook of western Montana and Idaho. In the hot winds of Kansas the warm air is just between a rain and an

approaching cool wave. Of course, the occurrence of such warm winds is easily foreseen if the weather map shows that conditions are favorable for the flow of air down the side of any sloping ground. When the slope is gentle and the rising air has deposited but little moisture on the windward side, then we have simply a warm wave or possibly a hot wave on the leeward side. Many of these advance from the Rocky Mountain region eastward in summer to the Atlantic coast. When the air is pushed from the high area over a ridge into the low area, the change of temperature is a compromise between the heat produced by compression as the air descends and the cooling due to expansion as the air passes from an area of high to one of low pressure. We thus have the hot waves that move eastward over Kansas and Texas. Some cases of high temperature on the Atlantic coast are apparently due to a continuation of these waves descending finally from the ridges of the Appalachian range. The heat shown in these warm waves depends essentially upon compression rather than on solar radiation; therefore, the hot waves occur in the night-time as well as in the day-time and with north as well as with south winds, provided only that the local topography is favorable. They advance over the country as fast as do the local winds, especially if they are of a local nature, but more frequently they are of a general nature and proceed with the upper currents, which are much slower in summer than in winter.

Prediction of Thunderstorms.

Many thunderstorms are of exceedingly small dimensions; they begin as clouds a mile in diameter but grow, perhaps, to twenty or thirty miles as they advance over the country before beginning to break up and disappear. Frequently a number of such storms are found pursuing parallel courses, side by side. In general, a storm-cloud cannot be formed of ascending air without the descent of a corresponding amount of air somewhere in the neighborhood. The atmosphere is, in general, a mixture of denser descending masses and lighter ascending masses. When a large mass of the upper air descends owing to its own superior gravity, it also slides along horizontally and the heavier air rolls along the surface of the earth,

spreading to the right and the left as it advances; the front of the advancing mass is almost invariably rolling over and over on itself and heaping up the opposing air. It constitutes a region of disturbance analogous, in some respects, to a long roll of breakers. In this region, at irregular points along the front, depending largely upon the irregularities of the earth's surface over which it rolls and the relative temperatures and moistures of the air, there are formed rain clouds, thunder clouds, hail storms, snowstorms, tornadoes, derechos, waterspouts and dust whirls.

The prediction of the occurrence of a thunderstorm depends upon the accuracy with which we can foresee the special combinations appropriate to the respective storms. But, in general, it is wiser to make no predictions of thunderstorms until one or more have occurred in some adjacent region; even then the most that can safely be predicted is to the effect that conditions are favorable for severe local storms moving eastward or northeast or southeast as the case may be. Such storms rarely travel 100 miles without breaking up and reforming.

Inasmuch as the stations of the general weather service are from 100 to 200 miles apart, the thunderstorms, whose diameters average five or ten miles, cannot be properly studied on the general weather map based on the telegraphic reports. In order to deal with them satisfactorily, it is customary to compile special maps from reports received by mail from as many special stations as possible. One station for every twenty-five square miles is needed to give satisfactory results, and a finer network than this is made use of when possible. The reports from special thunderstorm stations are generally systematized by being made upon postal cards that can be preserved as card-catalogues. The important observational data reported by each station consists of the following items: (*a*) time when thunder was first and last heard; (*b*) time of beginning and ending of rain; (*c*) the interval between lightning and thunder when nearest the observer; (*d*) the azimuthal bearing and apparent altitude of the storm cloud at several times in case it passes at a considerable distance. By plotting these items upon a chart on a large scale,

one is able to draw isobronts for the successive hours or quarter hours; these show the front of the storm at successive moments in its passage over the country. Such maps have been prepared in a few special cases for the United States and for northern Germany; but for several years in Bavaria and Austria and almost continuously since 1865 in France, where thunderstorms are exceedingly important to the agriculturist.

This method of charting and studying thunderstorms is also applicable to tornadoes and other local phenomena, the only difficulty being that a tornado is of still smaller dimensions than a thunderstorm, and, therefore, requires a closer network of stations.

The study of tornadoes and thunderstorms has long since shown that they occur, in the majority of cases, in the southeastern quadrant of an area of low pressure; they generally move eastward, more often northeast than southeast. The rate of motion, twenty to forty miles per hour, corresponds to the average velocity of the wind at the lower cloud level; they die away after a short period and entirely disappear within a few hours, but sometimes appear to break up and be again renewed even within this space of time.

When a broad area of the country is covered by a southwest wind there are always regions in which the wind is peculiarly liable to be turned upward by the irregularities of the ground and forced to form cumulus clouds and thunderstorms, or possibly tornadoes. On the other hand, within an area of high pressure and little wind but clear sky, the heated air at the surface of the ground is liable to ascend while adjacent air flows in; this topsy-turvy movement initiates a cumulus which eventually grows into a thunderstorm but rarely into a tornado. Besides these two classes there is a third class of thunderstorms that easily and rapidly develop into tornadoes; these form near the centre of a region of low pressure and in the border region between the southwest and the northwest winds. In all these cases it is not considered safe to predict the occurrence of thunderstorms or of tornadoes over any region of the country, no matter how favorable the conditions may appear to be, until one or more such storms have occurred, thereby assuring us that the unknown conditions in

the upper air are as favorable as those which are apparent on the map.

The art of the forecaster, therefore, consists both in perceiving the favorable region and in waiting until he is certain as to whether the phenomenon will be a dust-whirl, a derecho, a thunderstorm or a tornado, and then specifying the districts into which actual or incipient thunderstorms will move. He does not dare as yet to go so far as to analyze the physical and electrical conditions of the atmosphere and predict where thunderstorms or tornadoes must be formed, since one-half of such predictions would fail. The prediction as ordinarily made—" conditions are favorable for severe local storms to-morrow" —must be verified in at least three-fourths of the territory in order to be considered satisfactory from a meteorological point of view, and in order to justify putting the community to the expense and worry that such predictions cause.

The Prediction of Fog.

Fog and mist appear to be usually confined to a layer of air near the ground but a few hundred feet thick. In the interior of the country it is quite common to look from the hill-tops down upon the fog in the valleys. In such cases it may be safely anticipated that a clear, blue sky exists above the fog, and that the latter is formed, primarily, by the cooling of the lowest air, partly by contact with the surrounding cold objects and by radiation to the cold earth, but principally by direct radiation from this air into space. A lookout stationed at the mast-head of a vessel frequently has a comparatively clear horizon and can warn against collisions with vessels that are invisible to the pilot on deck.

On the seacoast, and especially over the ocean, as on the Banks of Newfoundland, the warm, southerly winds, laden with moisture, blowing over warm water, are rapidly transported into colder regions and mix with air that is resting over colder water. This mixture can, and undoubtedly does, produce the dangerous fogs of the North Atlantic Ocean. The cold air and water attending icebergs and floe ice, as these move southward and melt away, also contribute to the formation of fog. Like those over the land, fogs formed in this

way over the ocean are generally of but little depth, but they may occur over water when the sky is cloudy, whereas this rarely happens over land. The prediction of the land fog, and of the fog in the bays on the coast, may generally be made when the dew-point is near the temperature of the air and there is a prospect that the sky will be clear at night.

The fogs of our Pacific coast are formed in warm, moist air drawn landward by the indraught due to the heated interior; as the warm air passes over the cold current, close to the Pacific shore, before it piles up on the land, it is, by the double radiation down and up, cooled enough to be foggy day and night while over the water, and also at night-time while over the land; but, by mixing with the hot air over the land in the day-time, it is diluted and almost entirely dissipated when the sun shines, although it remains as dense as ever over the water. Therefore, the prediction of fog on the Pacific coast is subject to a regular periodicity, both diurnal and annual, that renders it comparatively a simple matter.

The Prediction of Dry, Cool, or Freezing Weather in California.

The presence of an area of high pressure over the mountains north and east of California ordinarily implies that air shall flow thence southwestward over the state. As this must descend, and, therefore, be warmed up, it becomes drier because its dew-point is apt to remain very low below freezing, while its temperature varies considerably between night and day. The sky being cloudless, we have here every condition favorable for the formation of very dry air, cool at night and warm by day, but so dry at all times that the evaporation from the leaves of tender plants will proceed far more rapidly than is beneficial and they will wilt. Both leaves and ground are cold by reason of the evaporation, the former may be frozen without being frosted.

The prediction of these cold, dry winds in California on the basis of an area of high pressure over the plateau to the north and east began in 1871, but has become an important matter since the development of the citrus industry, and is now practiced with considerable

success. Successful predictions of frosts have led to the extension of the system of smudges and various methods of warming the air in the orchards to prevent injury to the plants.

Analytical and Experimental Research Work.

In the preceding sections we have learned something as to what the national weather bureaus are actually doing as to meteorological observations and the practical utilization of the data. It may be safely stated that, consciously or unconsciously, each of these bureaus recognizes the fact that meteorology is at present hampered in its usefulness by the comparatively slight progress that has been made in the higher walks of this science. Observations as such can be and are made with the greatest accuracy; this constitutes a scientific survey of the atmosphere analogous to the biological or the geological survey of the surface of the earth; it is an accumulation of exact data for scientific study. But science has several aspects; it may be purely observational; it may be purely inductive, arriving at generalizations by a comprehensive view of a great number of facts; it may have a deductive aspect, as when we apply mathematics to the demonstration of the results that follow from elementary laws; finally there is an utilitarian aspect of science which implies the proper performance of useful work in accordance with elementary laws based on the logical study of scientific observations.

The proper aim of a weather bureau must be to do its part in the development of all four aspects of scientific activity: Observation, induction, deduction and application. Efforts have sometimes been made to show that a popular government is, and should be, a purely utilitarian and popular institution, and that its duty is to develop the art of applying the sciences, not that of constructing them. But every art is imperfect in its beginnings. If a weather bureau is to apply meteorological science for the benefit of the community, it must be careful to see to it that this art of prediction progresses equally with the general progress of the science, just as is the case in astronomy, chemistry and the exact sciences. Moreover, it must stimulate the growth of the highest phases of meteorological science; it must stimulate investigation in order that it may have a solid foundation whereon to build improvements in forecasting.

There must, therefore, be a certain proper proportion in the work of every weather bureau between the attention given, on the one hand, to observations and predictions, and, on the other hand, to investigation. It is only by the increase of knowledge in both these fields that the practical utility of a weather bureau can continue to respond to the increasing demands of the people who support it.

The experimental side of meteorology is usually less prominent than its observational side; nevertheless, there are many questions involved in this science that must be settled by experiment and measurement in physical laboratories, as distinguished from the observations made at meteorological stations.

First among the problems suitable for the physical laboratory are the innumerable details pertaining to the apparatus that must be used, and if these have not been settled by physicists properly so-called, they must be taken up by the experimental and theoretical meteorologists. Every form of barometer, thermometer, hygrometer, actinometer, rain-gauge, anemometer, etc., is beset with sources of error that must be investigated and tabulated before the instrument can give reliable results.

The physical constants pertaining to the atmosphere itself, such as its chemical composition, its weight per unit volume, the law of the relation between pressure and density and temperature, the specific heat of the air, the viscosity, the radiating and absorbing process, all require more careful determination.

Among the additional problems we note:

1. The peculiarities of the aqueous vapor, both for liquid water and solid frozen ice; its pressure and density at saturation; its behavior at certain critical temperatures.

2. The relation of the atmosphere and its vapor to heat, especially its power of conduction, radiation and absorption in various parts of the spectrum.

3. The resistance of the wind to obstacles and the flow of air around obstacles, as revealed in the photographs by the *Schleier* method.

4. The condensation of moisture and the growth of cloud particles

Fig. 1.—CUMULUS CLOUDS.

Fig. 2.—CUMULO-NIMBUS CLOUDS.

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in continuation of the researches of Carl Barus up to the formation of rain drops, snow flakes, sleet and hail.

These are but a few of the laboratory problems waiting for solution in order to clear up difficult points in theoretical meteorology.

From an analytical or mathematical point of view, meteorology offers some of the most interesting and difficult problems that the analyst has to deal with. It is but forty years since Ferrel gave the first approximate solutions of the equations that represent the motions of the atmosphere under the influence of gravity, centrifugal force and heat. It is scarcely thirty years since Stokes and Kirchhoff showed us how to introduce viscosity or gaseous friction into these equations of mechanics. Some general solutions of interesting questions have been published by Stokes, Helmholtz, Chree, Diro Kitao, Cottier, Overbeck, Sprung, Craig, and many others, but much more still remains to be done. It may be useless to attempt the problems of the general circulation in all its generality in the present state of mathematical analysis, but innumerable special problems attract our attention.

The progress of pure mathematics is steadily onward, and the difficulties that now deter the analyst from considering our problems will, eventually, be overcome. For the present at least, it may be wisest to seek for graphic methods and processes of quadrature which may enable us to arrive at approximate solutions of the complicated systems of equations that represent the inter-action of the nine elements that enter into the problem of the motions of the atmosphere. These elements are:

1. The attraction of gravitation holding the air down to the earth and also producing tidal effects.

2. The sun's heat expanding it into a compressible gas.

3. The compression of the air under its own weight.

4. The addition of a variable quantity of moisture in both the vaporous and cloudy conditions.

5. The difference of temperature between equatorial and polar regions, or between the top and bottom of the atmosphere, or between highlands and lowlands, or between continents and ice-fields and

ocean water, all of which produce relative motions between the different parts of the atmosphere.

6. The diurnal rotation of the atmosphere with the earth, thereby introducing a centrifugal force that varies with the latitude.

7. The frictional resistances which are of several kinds, (*a*) viscosity proper; (*b*) the resistance of irregularities on the earth's surface; (*c*) the resistance offered by slowly-moving air to that which is moving faster and impinges upon it.

8. The variable distribution of the temperature and the latent heat in the air, depending upon the quantity of moisture thrown into it by evaporation from the land and ocean.

9. The radiating power of the air which could be neglected if the atmosphere were perfectly dry and clean, but is quite considerable when we consider the vapor, the clouds and dust.

Add to all these the further consideration that when once set in motion, the atmosphere may, by some very delicate change in the conditions under which it is moving, assume some obscure form of discontinuous motion and we at once see that the difficulties of the analytical mechanics of meteorology challenge the intellectual power of man to overcome them.

Mathematical investigations are sometimes called theoretical, because they usually proceed by adopting simple fundamental laws, deducing therefrom definite results by mathematical processes. This is not theory in the sense of something vague and unnatural, fanciful and untrue, but is theory in the meaning of the old Latin term *theoria*, viz., a systematic presentation of a complete system of principles and results. A *theoria* is always the noblest exposition that man can devise of the works of nature.

CLIMATOLOGY AND ITS AIMS AND METHODS.

The climate of any locality includes both the average condition as to temperature, moisture, sunshine and other so-called meteorological elements, and also the extreme range of variability of these elements. Moreover, we are generally supposed to consider these factors, not so

much in connection with their physical causes as in relation to their results. We study the climate in its relation to agriculture, manufactures, commerce, animal life, and, especially, man himself. We usually look to the professional meteorological observer for the fundamental observations of atmospheric conditions, but we must look to the physicist for the determination of the character of the solar radiation, to the astronomer for the law of the duration and intensity of sunshine, and to the farmer for the character of the soil.

The complexity of all these different relations is too great to allow us to hope to cover the whole subject in these few pages. We shall merely refer to some prominent matters that affect agricultural and other industries in Maryland.

With regard to agriculture and the biological laws upon which its success depends, the subject of phenology claims our first attention, and forestry is but little less important. After these subjects a few words will follow relative to roads, windmills, damage from lightning, and minor problems.

Climatic Elements.

The leading climatologist of the world, Dr. Julius Hann of Vienna, in his "Handbook of Climatology," has given great precision to the numerical data that he considers characteristic of the climate of any place. The reader will find these enumerated in the following list:

1. The monthly and annual mean temperature of the air.
2. The extent of the mean diurnal range of temperature for each month.
3. The mean temperature at two specific hours, namely, the early morning and mid-afternoon.
4. The extreme limits, or total secular range, of the mean temperatures of the individual months.
5. The mean of the monthly and annual extreme temperatures, and the resulting non-periodic range.
6. The absolute highest and lowest temperatures that occur within a long interval of time.
7. The mean variability of the temperature as expressed by the differences of consecutive daily means.
8. Mean limit, or date, of frosts in spring and fall, and the number of consecutive days free from frosts.
9. The elements of solar radiation as measured by optical, chemical and thermal effects.
10. The elements of terrestrial radiation as measured by radiation thermometers.

11. The temperature of the ground at the surface, and to a depth of one or two yards.
12. The monthly means of the absolute quantity of moisture in the atmosphere.
13. The monthly means of the relative humidity of the air.
14. The total precipitation, as rain, snow, hail, dew and frost, by monthly and annual sums.
15. The maximum precipitation per day and per hour.
16. The number of days having 0.01 inch or more of precipitation, including dew or frost.
17. The percentage of rainy days in each month or the probability of a rainy day.
18. The number of days of snow, with the depth and duration of the snow covering.
19. The dates of first and last snowfall.
20. Similar data for the dates of hail.
21. Similar data for the dates of thunderstorms.
22. The amount of cloudy sky, expressed in decimals of the whole celestial hemisphere.
23. The percentage of cloudiness by monthly means, for three or more specific hours of observation.
24. The thickness of the cloud layer, or the amount of strong sunshine as shown by Campbell's sunshine recorder.
25. The number of foggy days, or the total number of hours of fog.
26. The number of nights with dew; also the quantity of dew.
27. The monthly means or total of wind velocity, or estimated wind force.
28. The frequency of winds from the eight principal points of the compass, and the frequency of calms.
29. The frequency of winds for each hour of observation and the diurnal changes in the winds.
30. The meteorological peculiarities of each wind direction, or the respective wind-roses for temperature, moisture, cloudiness and rainfall.
31. The mean annual barometric pressure.
32. The total evaporation, daily and monthly, or some equivalent factor, such as the depression of the dew-point combined with the velocity of the wind.
33. Variations in the gases contained in the atmosphere, provided they are suspected to be of importance.
34. Impurities in the atmosphere, such as the number of dust particles, and especially the number of spores or germs of organic life.
35. The proportions of ozone, the hyper-oxide of hydrogen, and nitric acid.
36. The electrical condition of the atmosphere, if there is any method of obtaining it.

To these we must add the following:

37. The sensations experienced by the observer, such as mild, balmy, invigorating, depressing, and other terms used to express the effect of the weather upon mankind.

38. The number of storm centres that pass over a given locality, or the storm frequency, monthly and annual.
39. Frequency of severe local storms.
40. The duration of twilight.
41. The blueness or haziness of the sky.
42. The number and extent of the sudden changes from warm to cold, or moist to dry weather, and vice versa.

Still other combinations will undoubtedly be required in many special investigations, but it is interesting to have the above long list as an indication of the thoroughness with which climatologists have already explored the relations of the climate to every branch of human industry.

The preparation of numerical tables embodying all these climatological data has, as yet, been hardly ever accomplished for American stations and for very few in Europe. The list, however, presents an ideal to the realization of which Hann has devoted his life, and Americans must emulate him in this work. The preparation of such climatological tables for a few points, such as Baltimore, Frederick, Annapolis, Cumberland, Dover, Norfolk, Washington, is already possible by reason of the accumulation of data, and their study would furnish appropriate subjects for university theses.

Phenology.

For many years past botanists have pursued the systematic observation and record of the various phases or epochs in the growth of plants, both wild and cultivated. The study of these records, and especially their relation to climate, constitutes phenology. The comparison of modern with ancient climates, or the comparison of the home climate with that of a distant region, is often largely dependent upon these phenological observations. The progress of the development of a plant seems to sum up, as it were, all the influences that can affect it. Of course, these are principally sunshine and water, soil and air, but there are also injurious insects and germs, and, sometimes, helpful insects and germs to be thought of, to say nothing of the variable characters of the original seeds. The soil in which the roots spread, and the exposure of the soil to the north and south are, undoubtedly, most important items; botanical climatology must take

account of the physical characteristics of the soil before it can consider the special atmospheric influences. It is the province of a state weather service to observe and study every feature that influences the development of plants, the quantity and quality of the crop, and even the harvesting and preservation of fruits and grains. The problems that are suggested in this connection are almost innumerable, and all are likely to repay careful attention. All studies in this connection must be pursued conjointly by the State Weather Service and the State Agricultural Experiment Stations. The determination of the climatic conditions prevailing on any spot goes a long way toward deciding whether a plant that flourishes in some other part of the world under similar climatic conditions can be transplanted successfully into the present locality. The whole question of the introduction and development of important and new industries hangs upon our knowledge of the relation between the climate and the plant and the possibility of developing in the plant a power of adaptation to slightly varied conditions.

Very comprehensive collections of statistics bearing on phenology have been made by several investigators, but we need only refer to the works of a few of these.

Reaumur was the first, in 1735, to make an exact comparison of the quantities of heat required to bring a plant up to any given stage of development. He adopted the sum of the mean daily temperatures as recorded by his thermometer in the shade as an index to the quantity of heat received by the plant from day to day. In the absence of numerous hourly observations of temperature, he used the average of the maximum and the minimum as a sufficiently close approximation to the average daily temperature. He found that for each successive year the sums of these daily temperatures was approximately constant for the period required by any given plant to attain any given stage of development, hence this constant sum is called the thermal constant in phenology. For instance, for the three growing months, April, May and June, 1734, the sum of his daily temperatures for 91 days was equivalent to 1,160 degrees Centigrade, but in 1735 it was only 1,015 degrees, whence he predicted that the ripening

of the vegetation in 1735 would be retarded as compared with the preceding year. He expanded this idea based on observations at one locality in France and suggested that comparisons be made between the thermal constants of the same plants in all parts of the world.

We see here an admirable suggestion for future work in the state services. When Reaumur's idea has been satisfactorily worked out for any given crop and locality, one should, from meteorological records alone, be able to predict the limiting date when it will first be practicable to begin the harvest. At present the farmer only knows that if the crop has been delayed by the weather the harvest will probably be late, but Reaumur's idea was to convert this approximate guess into an accurate prediction, and this result will probably be attained when we come to understand the subject better. In the further prosecution of this idea it will be necessary for the future investigator to repeat and elaborate the measurements and computations made by many phenologists during the past century.

Some eminent authorities have given up the problem as hopeless in view of the recognized power of every plant to adapt itself to every change of climate. Now a seed is so constructed that, when once planted, no matter how inhospitable the soil or climate, it will do its utmost to perfect new seeds that shall perpetuate the plant. But given a fairly uniform climate and surroundings, the times of ripening and the character of the new crop are as uniform as can be desired; therefore, within a limited range of error the prediction of the date and the character of the harvest can be made. This is practically done in a crude way by our great speculators and cultivators of every kind of crop. It is for the state service to give greater precision and value to these predictions and to make them useful to the farmers primarily.

In the development of Reaumur's ideas a number of modifications have been made in the method of computing the daily mean temperatures; thus Adanson disregarded all temperatures below freezing, taking only the sums of the positive temperatures on the centigrade scale, and, for simplicity, without introducing any large error, he took the beginning of the year as a starting-point for the summa-

tion. Boussingault adopted the principle that the duration of any vegetating period multiplied by the mean temperature of the air during that period would give a constant product; thus for winter wheat to ripen he found a sum total of from 1,900 to 2,000 degrees of mean daily air temperatures. In general, winter wheat grows very slowly, if at all, in earth and water at a temperature of freezing; therefore, it would seem that Boussingault's summation of the mean daily temperatures should be modified by omitting from consideration every case when the temperature is at or below freezing, and this has actually been done by most of the recent investigators. Gasparin rejected the temperature of the thermometer in the air and substituted in its place that of the thermometer in full sunlight and lying on the sod. Undoubtedly this represents much more nearly the temperature of the leaves and plants. Thus he obtained for wheat a sum total of 2,450 degrees Centigrade as a thermal constant for the interval between sowing and ripening of the grain. He also experimented with the temperature of a blackened metallic disk in the sunshine and the temperature of the sunny side of a vertical wall. He found the warmth of the air in sunshine as compared with that in the shade to be equivalent to a transportation in latitude of from three to six degrees southwards. He placed a thermometer in the centre of a hollow copper globe coated with lamp-black and recommended this to all observers, thereby preparing the way for the bright and black bulbs recommended by Violle in 1879 and still widely used in France. On this subject Gasparin[1] says:

"We see how much the different temperatures of the stems and the roots ought to modify the flow of the sap and there is here an interesting subject for physiological study which should redound to the profit of agriculture. The solar heat contributes also in a remarkable manner to cause the differences between the vegetation on the mountains and in the plains."

On mountain tops it is the heat of the surface soil and the roots in sunshine, and the effect of sunshine on the leaves that makes possible the existence of a great variety of phenogams. The direct action

[1] See page 84 of his *Météorologie Agricole*, Paris, 1844.

of the solar heat explains the possibility of raising cereals and other southern crops in high northern latitudes.

Carl Fritsch of Austria considers that the development of a plant depends principally upon temperature and moisture, but that the perfection of its reproductive processes depends upon the influence of direct sunlight. He enumerates nine different epochs in the history of the plant and gives in detail the observed dates of these epochs for 118 varieties, together with the corresponding meteorological data. His epochs are: For the annuals, the date of sowing and the date of first visible sprouting; the first formation of spikes or ears. For both annual and perennial forest trees, he adds the first unfolding of the leaf bud, namely, the frondescence, the first flower, the first ripe fruit, and, finally, the fall of the leaf or the time when the tree has shed fully one-half of its leaves. As some plants blossom a second time in the autumn, although they may not ripen their fruits, therefore he adds the second date of flowering.

Passing over many other investigators we will allude next to Hervé Mangon, who takes account of the shade temperatures of the air from the date of sowing up to the date of harvest, rejecting as unimportant or ineffective all cases where the mean daily temperature in the shade is less than 6 degrees Centigrade (the English use 42 degrees Fahrenheit as equivalent). By this method for the years 1870-79, he finds the total sum of the effective mean daily temperatures for ripening wheat in Normandy to vary between 2,219 and 2,517, and is able to make several important suggestions and practical rules as follows: (1) In a mild and uniform climate like that of northwest France there is always an advantage in sowing wheat early in the autumn. (2) By computing annually the sums of the degrees of the mean daily temperatures observed since the date of sowing and by consulting the numerical tables given by Mangon, one can calculate four or six weeks in advance with remarkable accuracy the date of the approaching harvest for the respective plants. The calculations given by him show that the uncertainty of the predicted date of harvest amounts to three or four days.

Hervé Mangon's computations have been repeated for Algeria by

Ballend, and deserve to be taken up more extensively in the United States under the auspices of state services.

There is another aspect to the same question. If for every plant there is a best temperature, sunshine and moisture, then the departures above that condition must act as injuriously as departures below it, and Coutagne has expressed in algebraic formulæ the law connecting the temperature with the rate of development. To be sure, Vantieghen and others found that his laws were very special and could not be applied to all stages of the plant. In fact, we have come to recognize that the plant is not an independent vitality, doing as it pleases with the chemicals that it receives from the soil and the air, but is simply a mechanism upon which and through which solar radiation acts. The plant does no work; it is the sunshine that contains the force that does the work. Now sunshine produces light, heat and chemical reactions; therefore, when we compare temperatures only with the development of the plant we may be neglecting those other components of sunshine that are equally important. We have here still another suggestion as to how the chemist and physicist, the photographer and the spectroscopist, and the bolometrist and astronomer must combine forces if we are to understand all the details of the relation between climate and crops.

In this country it is very common to experiment with seeds brought from foreign lands, but the study of relative climatology and phenology will prevent us from making many mistakes. Lippincott found that in England the length of period and sum of the temperatures required to perfect the crop of wheat were, in 1860, 59 days and 3,562 degrees Fahr.; in 1861, 50 days and 3,225°; in 1862, 56 days and 3,406°. In 1853 the mean temperature for two months was 2 degrees below normal; this cut off one-third of the crop and brought a famine that was already foreseen in July, 1853. On the other hand, it caused an increase of the exportation of wheat and flour from the United States, rising from 14,000,000 in 1852 and 19,000,000 in 1853, to 49,000,000 in 1854. A careful study of the local sums of rainfall, temperature and sunshine may enable one in general to foresee similar features and corresponding commercial changes.

Fig. 1.—NIMBUS CLOUDS.

Fig. 2.—FRACTO-CUMULUS CLOUDS.

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THE GEOGRAPHICAL DISTRIBUTION OF PLANTS.

The climatic service of a state forms part of the scientific organization which has now spread over the whole globe, laboring to acquire an insight into all natural phenomena that have anything to do with climate. Among these nothing has attracted more attention than the general distribution of animal and vegetable life throughout the globe. An interesting chapter of this subject seems to have been correctly written by Linsser in two memoirs published in 1867 and 1869. Linsser agreed with Erman as to the unsatisfactory character of the various hypotheses of preceding phenologists, and endeavored to give them greater precision. First of all, he invented a method of computing the sums of temperatures above freezing for each day of the year and for all parts of the globe for what may be called the normal plant. He computed the sums of these temperatures for the same plant in different latitudes and found more exactly than was known before that the same stages of development are attained by much smaller sum-totals of temperature at northern than at southern stations. There is, therefore, no uniform constant and no uniform minimum temperature, and yet there is a thermal law concealed in his figures. This law may be expressed as follows:

"Every individual plant possesses the ability to regulate its vital activity as demanded by the total heat available in its dwelling place, and also according to the habit inherited from its ancestor, that is to say, inherent in the construction of its seed so that individuals of the same species living in different places arrive at the same phase of development by utilizing the same proportions of the total heat to which they are accustomed. In other words, the rate of development is equal to the quotient of the effective temperatures to which the seed and young plant are exposed, divided by the normal total annual sums to which the mother plant had for many generations been accustomed." Applying this law to seeds that are transported either naturally or artificially from their homes to other places, we are able to predict approximately what their behavior will be. For instance, Von Baer observed that seeds of the cress that had been raised in St. Petersburg in latitude 60° N. and transported to

Matotschkin-schar in latitude 73° N. developed in July at only one-third the rate that they did in St. Petersburg in the month of May. Now the annual sums of positive temperatures for these two localities are 2,253 and 330 degrees Centigrade respectively, the ratio of which is 6.8. Again, the average temperature of May at St. Petersburg is 11.2° C., while that of July at the northern station is 4.4° C., and compounding these ratios we arrive at the relative rate of development observed by Von Baer. In general, seeds raised in northern zones grow more rapidly, ripen earlier, and give a richer harvest when they are transported southwards. Again, seeds of mountain plants when carried into the warm lowlands develop earlier, and all these experimental and natural phenomena harmonize with Linsser's results.

In his second memoir, Linsser considers the influence of moisture as well as temperature. Moisture brings nourishment to the plant, but the quantity of material within the plant that can be worked over so as to be useful to it must be proportional to the quantity of heat or sunshine received by it. There must be a certain definite ratio between the material, that is to say, the water or the rainfall, and the quantity of heat, that may be called the most favorable ratio. This corresponds to the case when the material on hand is completely used up by the sunshine. The fractional portion of the annual sum-total of heat that is needed to bring a plant up to any stage of vegetation is Linsser's first physiological constant, and the ratio of annual sunshine divided by annual rainfall is his local climatic constant, which is large when the climate is favorable to the growth of the plant. Linsser studied the charts of temperature, sunshine and rainfall for all of Europe, and gave most detailed computations for 118 species of plants and 31 phenological stations. There is scarcely any exception to the conclusions summarized by him. He says "there are two special laws regulating the life of every individual plant; first, the individual habit; second, the principle of economy as applied to heat and moisture. If the heat is deficient and goes through periodical changes, either annual or otherwise, that give the plant warning of the necessity of economy, then the whole life of the plant

is intimately dependent on the annual variation of heat, as in the north temperate zone, where the moisture is abundant; but if it is the moisture that is subject to large periodical changes while the heat is always abundant, then the cycle of vegetable life depends upon periodic changes in moisture, as in the case of the flora of Madeira. Again, if the variations in climate are such that insufficient heat and moisture may both frequently occur, then the law of economy stimulates the plant to develop in accordance with both these vicissitudes, as in the steppes of southern Russia and Bokhara."

This latter modification of Linsser's first law carries us a long way toward understanding how the great variety of plants have become domiciled in every region of the globe, but this is only a first step in the investigation of the development and the acclimatization of plants, and there is enough work left for every state service for a century to come.

The practical importance of Linsser's work seems to the writer far greater than is generally apprehended.[1]

Adaptability.

The ability of a plant to flourish under new climatic conditions has allowed the spread of the most diverse forms of vegetation over the whole globe. The study of this power or vitality has been pursued by three methods: (1) Microscopic examination, minute measurements, and detailed study of all the minutiæ in the structure and life of a plant; this is the method of physiological botany. (2) General measurements of special plats of cultivated plants raised from the same seed but in different parts of the globe, and, therefore, under different climatic conditions; this is the method of the agricultural experiment station. (3) The study of the general statistics of the annual harvests throughout the world, and the comparison of prevailing climatic conditions.

In all three of these lines of work the State Weather Service must be called upon for coöperation. The present condition of agriculture

[1] The whole subject of phenology is fully reviewed in an unpublished memoir compiled by the writer in 1891 for the use of the U. S. Weather Bureau.

and the extent of our available vegetable foods and economic plants are limited, not so much by our climate and soil as by our ignorance of the laws of nature affecting plant life. There are, probably, at least a hundred thousand varieties of plants existing in the world and available for man's use, but the number actually known to be in any way useful is less than ten per cent. of this, and the number employed directly as food is less than one per cent. There is, therefore, an almost unexplored botanical field from which to recover for the use of civilized man a great variety of foods and fruits still unknown to our arts. It remains only to investigate the climatic limits within which any plant will flourish and the climatic limits actually occurring in any region, such as the state of Maryland.

It must, however, be remembered that although frosts and droughts are the ordinary enemies of successful agriculture, yet a single frost or drought must not discourage one as to the possibility of profitable agriculture. For instance, frosts and freezes occur so rarely in the peninsula of Florida that the cultivation of delicate tropical fruits is profitable, notwithstanding the occasional complete destruction of the crop. In fact, such vicissitudes generally exterminate the enemies of the important plants so that for some years after the artificial cultivation is more profitable than ever. In the North and West it is by no means rare to have the early plants of spring killed by a late frost, thereby necessitating an entire replanting; but the farmer rarely thinks of being discouraged by such temporary misfortunes.

The general distribution of any plant over the earth's surface gives an insight into the climatic conditions that favor its growth, and this is the subject that first interested the early botanists. During the past fifty years a more detailed study has been made of the times of sprouting, leafing, flowering, fruiting, ripening and harvest, in their relation to sunshine, temperature and rain, as mentioned under phenology.

Superadded to this, there is now being accumulated a mass of experimental and statistical data as to the relation between the climate and the quantity and quality of the harvest; in fact, by careful

analysis, week by week, for several successive weeks, of selected plants representative of a large field of corn or wheat, it is now possible to estimate closely what the crop will be if normal climatic conditions prevail. In other words, the development of the average plant during an average season may be represented by a curved line, the general law of whose curvature is known; the exact curve proper to a given field and crop and year is precisely defined as soon as we have, from weekly observations, determined a few points in the early part of the curve.

In a recent letter Dr. Wiley says:

> I am not quite prepared to accept the statement that "a plant adapts itself so easily to a climate that it is sure to bring forth a crop," etc., because I am still of the opinion that climate is everything; of course, meaning by that, that with a given climate a soil can be prepared suitable to a plant, while with a given soil a climate cannot be prepared suitable to a plant.
>
> Given a proper temperature and the proper distribution of rainfall, there is scarcely a piece of land in the world which cannot be made to grow successfully a crop suited to the same conditions of precipitation and temperature. . . . It is also true that a plant carried into different climatic conditions may adapt itself for a time with a wonderful facility to the changed conditions, but in the course of time climate will confine the crop to its proper locality.
>
> One of the most striking illustrations of this, in my own experience, has been with the sorghum plant. The chief value of all the experiments which have been made by the Department of Agriculture with this plant is in finding climatic conditions suitable to its proper development. Having found these conditions, we have, in four years, brought this plant up from almost a non-saccharine, or at most a syrup-making plant, to a highly saccharine and sugar-producing one. Had it not been for the valuable help of the climate, we might have floundered about for many years before reaching these results.
>
> I am not, of course, unmindful of the influence of soil, but, as I have said before, we can make soil. Luxuriant gardens are now growing on the sands of Florida, and that country is destined to become a great agricultural garden. With a climate equable and certain, the farmer is encouraged to go ahead and produce a soil which is sufficient to sustain all growing crops. All the farmer has to do is to press the soil-button and the climate does the rest.

The importance of the study of climate thus impressively stated should not blind us to the fact that, along with the acclimatization of the plant, there are also in progress various important modifications

of the methods of farming, so that methods and plants combine together to hasten the so-called acclimatization.

Soil Temperature.

The temperature of the soil does not depend, by way of cause and effect, primarily on the temperature of the air. It is not warmed by conduction of heat from the atmosphere, but by the direct absorption of the solar or other radiation that falls upon it and by the heat brought down by rain. The sunshine is, to a slight extent (five or ten per cent.), reflected from the particles of the earth's surface according to the laws of simple reflection; the remainder is absorbed by the surface and warms it. The warmed surface layer immediately sends back a small quantity, five or ten per cent., by radiation, into the atmosphere and through it into space, but it gives up a larger part, perhaps fifty per cent., by conduction, to the adjacent layer of air which, being thus warmed, quickly rises and thus this fifty per cent. of heat is, by convection currents, distributed through the atmosphere and eventually radiated back from it into space. The remainder, perhaps forty per cent. of the coincident solar heat, is by conduction carried downward a little way into the solid earth; a large portion is consumed in the evaporation of water and returns to the atmosphere with the aqueous vapor; the rest goes on downward, warming the soil and partly returning to the surface until finally a small percentage of it arrives at a layer thirty to fifty feet below the earth's surface where the gradient of temperature just in front of it is the same as that just behind it; here the heat would accumulate and push its way still deeper were it not that by this time, in most cases, the annual changes in temperature at the earth's surface, where the wave of heat started, have brought about a deficiency just below the earth's surface. The wave which had reached the depth of thirty or fifty feet now finds the temperature gradient just above it beginning to reverse, wherefore the heat begins to flow back, upward and outward. In this manner the temperature of the ground increases downward to a depth of a few yards and then goes upward in diurnal and annual fluctuations, interspersed with irregular changes depending on cloud and rain, snow and wind, almost all of which are

easily recognized by examining the system of curves representing the earth's temperatures at different depths at any station.

The ground is warmed by conduction from the air only in the case when the temperature of the surface soil is lower than that of the air, and although this happens frequently, yet the quantity of heat thereby communicated to the ground is comparatively slight owing to the small specific heat of the atmosphere.[1] But when rain and snow fall, then the heat formerly contained in the atmospheric vapor is quickly brought down to the surface and directly conducted into the soil, and the latter will be warmed or cooled according as the rain or snow is warmer or cooler than the ground; in general, the warming of the soil by warm rain is far less important than the cooling by cold rains, melting snows, and evaporating winds.

When clouds intervene the soil receives a smaller proportion of solar heat, and the proportion diminishes as the thickness of the cloud layer increases, or as the proportion of cloudy sky to clear sky becomes greater. We may adopt the approximate rule that the warming effect of the sunshine is inversely as the cloudiness of the sky within 45 degrees of the zenith; thus for a sky wholly covered by cumulus or stratus, the direct solar heat at the ground is 0; but when covered by cirrus or cirro-cumulus, or cirro-stratus, the solar heat is about 8, while for 0 cloudiness the radiation that the observer receives is 10.

The motions of the clouds do not affect the sum-total of the intensity of the sunshine, but the variations of cloudiness are so important that it is best to make use of some form of sunshine recorder, or, still better, some form of integrating actinometer as a means of determining the relative effectiveness of the sunshine for any hour or day. If any such instrument shows that during any given hour, with the sun at a known altitude, the duration or the effectiveness of the sunshine was the nth part of the maximum value for clear sky, then we may assume that the heating effect of the sun on the surface of the soil was the nth part of its maximum value and may thus ascertain, and, if necessary, approximately compute, the irregularities of the

[1] This point has been carefully developed by Maurer, Zürich, 1885.

waves of heat that penetrate the soil. But these irregularities are directly shown and measured by thermometers buried in the soil at different depths, and the observation of such thermometers is an essential item in the study of climate and vegetation. The absence of these observations frequently necessitates much labor in very unsatisfactory efforts to obtain the approximate soil temperature from the ordinary observations of air temperature, radiation, thermometers, clouds and sunshine.

Fortunately, during the past few years many of the agricultural experiment stations of the United States have begun the observation of soil temperatures, as distinguished from the deep-earth temperatures that interest the student of terrestrial physics but do not affect the agriculturist.

The soil thermometers used for this purpose are made in sets of 4 or 6, whose bulbs are respectively 3, 6, 9, 12, 24, 36, 48 inches below the surface of the soil. The observations already discussed show the great influence of cloud, snow, rain, drainage, altitude above sea, coarseness and porosity of the soil at considerable depths, and equally the effect of cultivation, ploughing and mulching on the surface. A single thermometer giving the temperature at one foot beneath the surface will give the farmer many surprising facts for comparison with the growth and ripening of his crops.

Sunshine.

Climatology considers first the temperature of the air as given by thermometers that are shaded from the effect of sunshine; this is the temperature of the air very nearly as given by the sling thermometer, and is that that is needed in dynamic meteorology. But the sunshine produces important chemical effects besides its thermal effects, and these have no simple relation to each other. It is therefore, very important that we have some method of recording the total or general radiation from the sun or from the sun and sky combined. Up to the early part of this century the optical and thermal effects of sunshine were assumed to be due to certain imponderable kinds of matter called light and heat that were supposed to be combined in the complex solar rays, but which can be separated from each other.

But we now believe it safer to speak of the sunshine as a complex influence which we have not yet analyzed and of whose exact nature in relation to interstellar ether and atoms we know practically nothing, but whose effects, when it acts upon terrestrial matter, we know and study as phenomena of light, heat, electricity, magnetism, gravitation, chemistry and vitality.

Plants respire during both day and night. The pores of the leaves are always absorbing and emitting gases; but when the sun shines on the leaves, and more especially with the help of the yellow part of the spectrum, then the chlorophyl in the leaf cells is able to decompose the carbonic acid that is absorbed, retaining the carbon and rejecting the oxygen which is emitted. This decomposition of carbonic acid gas does not generally take place in the absence of sunshine or yellow light; therefore, during the night, the air that is inspired is always subsequently expired without any great change in its chemical nature. It is sometimes said that the leaves emit carbonic acid gas at night but oxygen by day, but it may be more properly said they emit more oxygen by day than by night.

The growing plant absorbs more carbon from the air and more nitrogen from the soil than it loses by any process, and is continually increasing its leaf surface and the nutrition in its sap, laying up a store of nutriment for future use. This process ceases in the case of annual plants when the seed or grain, or fruit, begins to ripen, from which time forward the seed cells make a draft principally upon the nutriment already stored up in the plant, which goes to perfect the seed; therefore, in this stage of its growth the plant needs less water than before, but its roots still have the power of absorbing water.

As the sunshine represents the source from which the plant draws all its power to do chemical work, therefore the sunshine-recorder and the actinometer are instruments of primary importance to agricultural science. These pieces of apparatus should therefore form a part of the outfit of every climatological observatory, and will be fully described in a future page.

Irrigation.

The fact above mentioned, that the roots of the plant still have the power of absorbing water up to the last stage of its growth, serves to show why it is that if too much rain or irrigation occurs in the last stage of the ripening of the crop the sap will be unnecessarily diluted and there will result a seed or fruit that is heavy with an excess of water. This will dry out after the harvest if it has an opportunity, but if it has not, on account of too close storage or damp weather, then it will remain in the seed and render the latter more subject to injury from fungi, whose spores are always floating in the air seeking a moist nidus or resting place favorable to their growth. Moreover, such moist seeds give a heavy green harvest but a light, dry crop.

Thus it happens that the distribution of natural climatic heat and moisture as to time is quite as important as the distribution as to quantity in their effects on the local harvest.

Apparently the time of ripening of the harvest depends wholly upon the chronological distribution of the supply of water and sunshine, but the quantity and quality of the harvest, which are the important practical results to the farmer, depend upon the nutrition carried into the plant by the water that is absorbed by the roots.

The satisfactory determination of the right time for irrigation and of the proper quantity of water, in order to produce the best crop in a soil of a given richness is the special problem of those planters who depend mostly upon irrigation for successful agriculture. In general, it may be said that our ordinary seeds have long since been selected and acclimatized with a view to success in a climate where abundance of moisture is available. Hence our crops are not nearly as likely to be injured by excess of rain as by deficiency or drought. Therefore, in almost every section, from the Rocky Mountains to the Atlantic, the highest success can only be attained by making provision for artificial irrigation in times of drought. The exact time for irrigation and the quantity of water to be used depend upon the seed and the soil, as also on the evaporation, which latter is due to dryness of the air, velocity of the wind, and the character of the soil. When

artificial watering or irrigation is needed to supplement natural rain, one must seek to approximate, as closely as practicable, to the conditions presented by the climates of the countries where the seed originated; he must be guided by the customs in countries where irrigation is the only resource, or else by the conditions presented in his own country during the seasons that are known to have produced the best crops.

The best rules as to irrigation are discovered by the comparative study of the climate, or rather the weather, of the best crop years, as giving us some idea of the characteristics of the ideal climate that is best for any crop and of the soil.

Climatic Laboratories.

In so far as we study climate for the sake of determining its influence on animals and plants, our labors are hampered by the great vicissitudes, the inevitable irregularities, in the natural climate of every spot in this portion of the United States. Even if our studies were conducted in the most equable natural climates, we should still find even there annoying departures from normal conditions that introduce errors into our conclusions. The importance of careful experimentation on a rather large scale was dwelt upon by A. de Candolle, in a memoir translated in the American Journal of Science in 1866. Since that date numerous experiment stations have carried out the ideas emphasized by him, but much still remains to be done. Experiments as to the determination of the influence of temperature, of air and soil, moisture in the soil, and amount of sunlight or electric light, have been made on a few plants. In a general way the influence of each of these taken separately is known approximately, but we still need the more elaborate establishment in which plots of soil of a square rod in area may be subjected to cultivation so as to raise crops of wheat, corn, etc., under the most diverse conditions. With the electric light and the refrigerating machinery we should be able to keep the plants at their maximum efficiency in each stage of their growth and secure perfect seeds for the next crop. All this means an immense amount of labor and care and the overcoming of innumerable obstacles, but this must be the ultimate goal to be attained in the study of the relation between climate and crop.

The ordinary hot-house and cold-bed experiments relate to the effect of the moisture and temperature of the air, but a wider range of conditions should be tried and a larger area than the square foot of surface in a large pot. There should be a way of altering the temperature and moisture of the soil independently of that of the air, and, especially, a method of carefully controlling the sunshine, skylight, or other radiation.

Gardens, Nurseries and Arboretums.

These and similar terms refer to the establishments out of doors where flowers, plants and trees are subject to the vicissitudes of the natural climate. In fact, every plot is, to a certain extent, an experimental garden. The landscape gardener and the planter are alike interested in the development of new and useful shrubs. They are continually on the lookout for plants that may be brought from distant localities and acclimatized in their own grounds. They are essentially students of comparative climatology, and the progress of their work, which means the welfare of the state, is facilitated in just so far as the State Weather Service can make known the relative climatology of this and distant localities. The literature of meteorology already presents us with excellent general treatises, such as those of Hann on general climatology and Woeikof on the climates of the globe or of Gasparin on agricultural meteorology. These must now be supplemented by more minute treatises on the climates within a given state and the climates appropriate to given plants. Knowing the facts thus obtained, we shall be able to introduce into the state, and domicile among us, a great variety of useful and desirable trees, shrubs, flowers, grains and textile plants.

Laboratory Experiments.

The wide range of desirable experimentation in this line of work may be inferred from the following remarks on only one problem among the many that have been undertaken. A wide course of reading shows that the respective experiments may be considered as belonging both to the physiology of plants and to the study of relative climatology.

The influence of a uniform temperature on the germination of the seed was first experimentally studied by de Candolle, and numerous others have elaborated his work. In general, some, but not many seeds, germinate at the temperature of melting ice. At a few degrees above this other seeds begin to germinate, and as higher temperatures are experimented with they are found to germinate more rapidly, requiring only two, three or four days, instead of the ten, fifteen or twenty that are required at freezing temperatures. At about 50 degrees Centigrade, or higher, almost every kind of seed again fails to germinate; the most remarkable exception is the seed of the *Sesamun orientale*, belonging to the family of the *Pedalinea*, which germinates freely in nine days at a uniform temperature of 12 or 13 degrees Centigrade, but when exposed to temperatures between 50 and 57, one seed in five germinated in 25.7 hours at an average temperature of 51.5 degrees Centigrade.

In general, there is a minimum temperature at which any seed will germinate, and this may be below freezing; there is also a maximum limit, and more especially is there a most favorable temperature. The species that require high temperatures as the minimum for germination are usually from warm countries; such species cannot flourish in cold countries, for if they do germinate there it happens too late in the springtime and they cannot ripen their fruits before winter. The species that germinate at low temperatures will, of course, also do so at moderately higher temperatures, and some of them can endure temperate climates permanently but they are apt to germinate too early in the spring and be killed by late frosts. The upper limit of temperature beyond which germination is impossible depends very much upon the amount of moisture available.

The geographical distribution of any plant is the more extensive in proportion as the range of temperature within which its germination is possible becomes larger.

At the so-called best temperature for germination of any given variety the time required for that phase is shorter than for any other temperature and increases to infinity, that is to say, to impossibility at the maximum and minimum limits, here, therefore, the seed will

rot or disintegrate rather than germinate. In estimating the probable time at which any seed that has been sown in the ground will germinate at a given temperature of the soil, we first determine how far that temperature is above or below the best temperature for the plant and compare with the experimental table based on the work of de Candolle and others, leaving out of consideration, however, the so-called useless or ineffective temperatures below the minimum and at which no progress is made in germination.

The farmer who has made daily records of the temperature of the soil at depths of one, three and six inches may thus anticipate with considerable accuracy the dates on which the sprouts from the invisible seeds will appear at the surface.

The time required for sprouting diminishes as the temperature increases, and Quetelet proposed to take account of the square of the temperature to which the seed is exposed; but if the temperatures are counted from a certain best temperature, then we attain sufficient exactness by considering only the departures from that and need not consider the squares of the departures. According to the experiments at Cornell University Experiment Station, sprouting takes place more rapidly in rather dry soil and is retarded if the soil is decidedly wet, and this acceleration or retardation does not seem to depend upon temperature. The exposure to light retards some seeds but does not affect others. This question of the effect of exposure to light has been investigated by many, and a summary of the results is given by Pauchon, who says: "It appears to me impossible to draw any conclusion whatever from all these facts. . . . The problem is certainly much more complex than appears at first sight. There is every reason to suppose that the action of light is not the same under all the conditions of temperature which obtained during these experiments." He objects to the adoption of the visible development of the embryo as a scientific basis of appreciating the relative influence of light and heat, and declares that he will take for the basis of a new series of observations the variations in respiration as a measure of the germinal activity of the vegetable embryo. He demonstrates that sunlight exercises an accelerating influence upon the absorption of oxygen by seeds in the process of germination.

Fig. 1.—STRATUS CLOUDS.

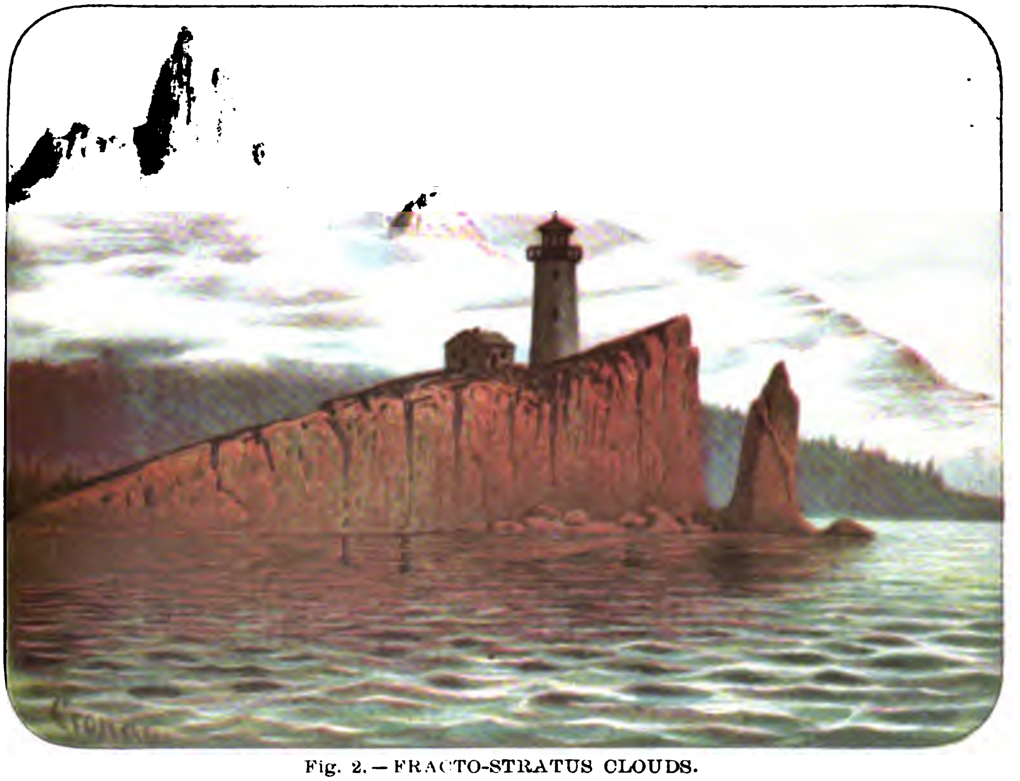


Fig. 2.—FRACTO-STRATUS CLOUDS.

Published by permission of the Hydrographic Office, Navy Department.

These conclusions emphasize the importance of including in the work of the State Weather Service not only the measurement of the duration of sunshine, as is done at all regular weather bureau stations, and, in fact, generally throughout the world, by thermometric or photographic apparatus, but also especially the measurement of the intensity of sunshine by actinometric methods, which are described in the last section of this paper. Each stage in the growth of a plant offers abundant opportunity for similar studies into the respective provinces of moisture, light and heat.

Lightning and Wind.

The damage done to forests is not only caused by drought, wind and insects, but is due in many instances to the destructive fires that are started by lightning, or, sometimes, by sparks produced in connection with landslides. Lightning directly injures only a few trees, but through resulting forest fires it becomes a very serious matter. The effect of the wind is to destroy all the overgrown and feebler trees, but the more severe winds, of course, injure the mature and valuable trees. In most parts of the country high winds really do a vast amount of damage, and protection from such injury by a proper arrangement of the timber is an essential item in forest management. Mr. Austin Cary tells me that in Maine and New Hampshire much attention has been given to this subject: "The spruce forests having surface roots are especially liable to be thrown down. A heavy wind in a time of very wet soil is most disastrous. Whole townships have been practically ruined in this way. Our destructive winds are mostly from the northwest, and all our worst cases show the trees pointing to the southeast."

The destruction of barns, houses, cattle and farm produce in general is a matter well worth statistical investigation. The value of the lightning rod as a protection is still considered problematic by many; the question should be settled by careful inquiry.

The statistics of destruction by wind are as yet too imperfect to warrant more than the recommendation that this subject be carefully examined for the state of Maryland.

Cold Years and Forest Growth.

The cold years of 1812 and 1816 had a notable effect in diminishing and altering the forest growth of New England. Their effect was well brought out by Mr. Cary in his study of this subject. Some measurements of my own on the annual rings of growth of a group of trees in the Adirondack region also show the same fact. In general, the annual rings of an aged tree are a permanent record of the total climatic influence, year by year, for several centuries past. By comparing recent annual rings with corresponding recent climatic records, we may deduce a formula or a method for inferring approximately what the climate must have been to have produced a given amount of growth in the earlier years of the tree's existence.

It would seem extremely useful and proper for a state weather service to contribute thus effectively to our knowledge of the ancient climate and its relation to forest growth. It is not uncommon to discover ancient trees and forests preserved either by silicification of the wood or by burial under ground or under bogs, sometimes in salt water and sometimes in fresh. The measurement of the annual rings of growth will eventually give us some clue as to the climatology of former geological ages. In a general way these rings are known to demonstrate that, so far as sunshine and cloudiness and the chemical composition of the atmosphere, the rainfall and the seasonal changes are concerned, there have for ages been only limited and relatively slight oscillations at any locality.

The Cultivation of the Sugar Beet.

This industry has begun to assume considerable importance in the United States under the encouragement of the Department of Agriculture. In order to ascertain what regions in the United States had climates adapted to the varieties of beet cultivated in Europe, search was made among meteorological records accessible to the Department, yet a large amount of experimental planting was necessary and large sums of money were lost. This was, however, only a small percentage of what would otherwise have been spent in order

to ascertain the limit within which sugar can be profitably made. The last report on this subject by Dr. H. W. Wiley,[1] says:

"One special object which will be kept in view is to prevent those intending to engage in this industry from going wrong in the beginning and squandering their money and time in battling with problems that science has already met and overcome. . . . There will probably be found for many years to come in the United States more enthusiasm than knowledge connected with the sugar beet, and the result of this will be, unless great care is taken, that many ventures will be made which will result in financial disaster, disaster which could have been avoided by a thorough comprehension of the fundamental principles of the industry. . . . The chemical processes are no longer legitimate subjects for public experiments, the great problem in this country is the agricultural one. . . . The studies which have been made heretofore in regard to climatic conditions have been of such a nature as to locate in a general way the areas in the United States suitable for the culture of the sugar beet."

The meteorological data accessible to Dr. Wiley in 1890 indicated that Delaware could possibly raise sugar beets profitably, but the additional data available in compiling his bulletin of 1897 showed that not only Delaware but a part of Maryland also came within the favorable zone for beets, and this portion of the state comprises in fact all west of Cumberland. As the map compiled by Dr. Wiley in March, 1898, is of importance to the citizens of the United States, he has prepared a revised copy, and that portion which relates to Maryland, Delaware and the neighboring states particularly interests us. This map shows the isothermal lines for June, July and August. The isotherm of 70 degrees Fahrenheit deflects considerably to the north and south as it passes from Albany, N. Y., southwestward until the Allegheny mountains are crossed. It is assumed that the best beet sugar zone is comprised in the region for which the mean temperature during June, July and August is between 69 and 71 degrees Fahrenheit, and for which also the rainfall is favorable. Sugar beet plantations must expect to struggle against climatic peculiarities in proportion as they are located at a greater or less distance from this zone of favorable temperature and rainfall. But when we consider how sparsely the meteorological stations are scattered over the United States, and how few were employed by Mr. Henry in preparing the

[1] Farmers' Bulletin, No. 52, U. S. Dept. of Agric.

normals for Dr. Wiley's use, we must emphasize the fact that undoubtedly there are numerous spots in Maryland and Delaware highly favorable to beet culture that are not indicated upon this general map. Of course one may take his chances and hope by a few successful annual crops to fairly counterbalance the disappointment of other unsuccessful years. But it is desirable to save the planter from costly experiments. A few years of inexpensive meteorological observation ought to suffice to establish the limits of possible success so far as the climate is concerned; after that the condition of the soil and the general state of agriculture in the favorable zones must define still more narrowly the regions where success is probable. As to the relation between climate and beet culture we venture on the following long quotation from Dr. Wiley's bulletin:

"It is evident that one of the first things to be considered, after the soil itself, in connection with the sugar beet industry is the climate. The sugar beet is a plant very susceptible to climatic conditions. At the beginning of its growth the beet plant is peculiarly helpless. It cannot lift, in passing from the new germ to the plant, the lightest clod. A rain which packs the surface of the soil immediately after the germination will sometimes prevent the plant from reaching the light. After the plant is established it requires a considerable quantity of water for its proper growth; this water must be supplied either by the rainfall of the locality, by irrigation, or by the subsoil. High temperatures extending over long periods of time are peculiarly injurious to the storing of sugar in the tuber. . . . Since the production of sugar in the leaf of a plant is a joint function of the chlorophyl cells and sunlight, it is found that the higher northern latitudes where the summer days are exceptionally long and the nights are correspondingly short, tend to produce, other conditions being the same, a beet rich in sugar. In Europe the great centers of the beet sugar industry are in regions far to the north, in fact so far north as to make it impracticable ever to expect in this country to establish the centers of this industry on the same parallels of latitude. . . . The vicissitudes of climatic conditions in northern Europe are also less marked than they are in the United States. Throughout the beet-growing area of Europe it is expected that the summers will be mild. They are not attended with many days of excessive heat. Spring comes early and permanently; the autumn comes slowly and late. In France and Belgium a severe frost is not expected in May nor is it anticipated that ice of considerable thickness will form in October. The summer days in those localities are considerably longer than even in the more northern portions of our country, and at least an hour longer than in the centers of our greatest agricultural prosperity. . . . In the light of the data at hand in the publication of previous reports, it has been assumed that the beet sugar zone of the United States would be

found located over an area of which the southern limit would be marked by the mean isotherm of 71 degrees for the summer of June, July and August. . . . This assumption is based upon so many independent conditions as to render it only useful as a working basis. In connection with the temperature must be considered the rainfall, the contour and nature of the soil, the possibility of irrigation, the abundance of subsoil, and a variety of non-meteorological matters."

As the result of the year's work in Maryland, Mr. Wiley makes the following statements on page 77:

"The whole number of samples received from this state was twenty-nine. The mean size of the beets was nineteen ounces, the mean percentage of sugar, 11.4, and the mean purity of the juices, 79.1. In respect to the size the samples from Maryland were about the mean. The purity of the juice was almost up to the minimum standard, but the percentage of sugar in the beet is about 0.6 less than is advisable for manufacture.

"In regard to climatic conditions there is a considerable area along the Eastern Shore next to the Ocean where the average summer temperature is 71. In the western part of the State the isotherm of 70 degrees may again be found. Lying immediately south of the isotherm of 71 in the northern portion of Maryland are found some very fine valley lands where the conditions of culture may be considered favorable. These lands are underlaid by limestone, which in many places comes to the surface. Theoretically they are a little too warm for the most successful culture, but lying so near the favorable thermal belt, these offer a reasonable expectation of successful culture in many localities. In the western part of the state where the thermal conditions are favorable we find the mountain ranges, and the low temperature of the summer is due to the high elevation. The quantity of tablelands upon the tops of the mountains is not sufficiently great to warrant the expectation of the founding of a great industry. There is no doubt, however, of a possibility of growing very rich beets on these tablelands. In general it may be said that the state of Maryland is not very favorably situated for the culture of sugar beets, but there are circumscribed localities within the state where it is desirable to conduct further experiments."

Dr. Wiley shows that the western portion of Maryland, as well as its eastern Atlantic coast, has the appropriate temperatures, but the rainfall observations are not yet known with sufficient detail to show with certainty whether the western portion will be as advantageous as the eastern portion. He says: "Judging by the temperature and the annual rainfall the cultivation of the sugar beet might be successfully inaugurated along the Atlantic coast and Eastern Shore; in fact practically over the whole of the southern portion of the East-

ern Shore of Maryland. . . . Although the general tendency in this region is in the direction of a too high temperature and too few hours of sunshine."

This paragraph will enforce the general truth that the State Weather Service, by increased observations of rainfall, temperature and sunshine, must endeavor to assist the farmers in the selection of localities, which, at least four years out of five, are favorable to the success of the sugar beet.

Within a certain range of climatic conditions every plant learns to adapt itself to its locality, and the principal question in successful farming is, what percentage of the seasons will be favorable? No one expects a great harvest every year; success is always a matter of balancing good seasons against bad ones. In the special matter of beet sugar almost as much depends upon slight variations in the chemicals and conditions of manufacture as upon the original plant and climate. We have here a wide field in which the State Weather Service, the Agricultural Experiment Station and chemists must coöperate for the benefit of the commonwealth.

Climatic Influences of Forests and Agriculture.

For years disputes have been waged over the question whether the forests have any appreciable influence on climate. Of course the same question can be raised with regard to the plowed fields and growing crops of the farmer. If the land is originally covered with forest, its destruction followed by a growth of grass and scrubs or some cultivated crop can hardly fail to produce some change in local temperatures near the surface of the ground. The temperature of the air within fifty feet of the soil depends intimately on the character of the surface of the ground; the difference between the air in a forest and that over a plowed field must be almost as great as that, in the other direction, between the forest and the ocean. It is not difficult to define these differences in precise numbers so far as temperature, humidity of the air and wind are concerned, but there does not appear to be any appreciable change as regards rainfall, cloudiness or stormy weather. The last three features of climate depend upon the general atmospheric influences that are at work far

above the ground. An elaborate exposition of forest influences has been published,[1] from which we may condense a few conclusions, which, however, would seem apparent without any elaborate system of observations.

In general, over a bare region, as compared with a forested area, the temperatures of the soil and of the air are exposed to greater vicissitudes, hotter by day during the summer and cooler by night during the winter. This effect, of course, increases with the size of the trees and the density of the foliage. In the foliage of the tree the mean temperature of the air is rather higher than at the same elevation over open fields, owing to the stoppage of the sunshine by the leaves and limbs. In general, the action of the forest tends to produce a change in the vertical distribution of temperature. The annual evaporation within the forests is about one-half of that in the open field; this is evidently due partly to the coolness in the shade of the forest and partly to the absence of strong winds. On the other hand, the quantity of moisture thrown into the air by transpiration from the leaves of the trees may or may not be more than that from a horizontal surface of water of the same extent and under the same conditions as to sunshine and wind; in this matter everything depends upon the character of the forestation. The total annual amount of transpiration as observed in forests of oaks and beeches in central Europe is about one-quarter of the total annual precipitation. It is commonly said that the rainfall within the forest area is greater than on the open ground, but I have shown in an appendix to Bulletin No. 7, above mentioned, that the gauges in open places catch less rain than they should owing to the influence of the stronger wind, and that when the gauges have been properly corrected there is found to be no appreciable difference in the amount of rainfall over the forest and over the open land.

The question as to whether the forests have any influence upon the occurrence or the movement of destructive hailstorms may still be debatable for America, but it has been settled negatively for France, notwithstanding the study of the subject by Becquerel, who

[1] U. S. Dept. of Agric., Forestry Division, Bull. No. 7, 1893.

succeeded merely in proving that destructive hailstorms keep outside of the forests. In fact, severe hailstorms occur both within and without the forest, and the question is one as to the relative amount of destruction in the two cases. Of course the tough forest trees do not suffer so severely as the delicate plants that are in the fields. In general, however, if hailstorms are due to the uprush of special areas of hot, moist air then we ought to expect them to be more frequent and more violent over the cleared areas if these are sufficiently large. But the fact is that climatic conditions that favor destructive hail do not favor the growth of great forests. It is the meteorological climate that produces forests in one place and hailstorms in another, and not the forests that prevent hail.

There is a very long list of detailed questions as to the differences in climate depending upon topography and the covering of the earth; mountainous, hilly and flat countries have each their peculiarities; the forests, the plantations, the prairies and the water surfaces differ appreciably from each other. The differences between cities and the surrounding country are apparent to every one. We are liable to exaggerate the amount and quality of these differences; the memory and the sensations are not safe guides. It is the place of state services to investigate these questions as carefully and as minutely as their importance may seem to demand. In doing so, many popular errors and prejudices will be dissipated and new facts or laws discovered that will prove of interest and possibly of value.

Reforestation.

While some parts of Maryland still retain virgin forests, yet by far the greater portion has been cleared, planted and cultivated and again returned to forest growth only to be cleared again as at present. As a rule, every acre of land ought to be allowed to run fallow every few years, some say every seventh year, but more than this it should also be allowed to return to forest once in a century, or perhaps every alternate fifty years. There is nothing that so improves cultivated land as does the humid soil of a forest region. There is nothing that conserves little springs of water so well as a forest covering. There is nothing more beautiful to the eye of man and beast and

bird than the thick, green forest. There is no crop of greater value than fine timber and other forest products. From every point of view, practical and esthetic, hygienic and agricultural, Maryland needs a wise, far-sighted forest policy. Education in this matter requires a school of forestry and students of the art of raising and preserving forest trees. This is a branch of agriculture, as distinct from ordinary plantation work as that is from horticulture. But there is no reason why it should be neglected since the best authorities on the subject have presented convincing figures to show that in the long run the cultivation of the forest is as profitable as any other agrarian activity. This may seem incredible to those who have only cleared away the forests and immediately begun to raise enormous crops of corn, wheat and tobacco, but further experience shows that there soon comes a limit to these crops; heavy expenses are then incurred for fertilizers, drainage and better seed, and, finally, after fifty years or more, the land is abandoned as worn out. Meanwhile the neighboring forest has continued to flourish and its timber has become more valuable, so that the farmer turns lumberman and proceeds again to cut down all that is within his reach. Now the true remedy for this is to remember, first of all, that certain lands will always do better in forest than in any other crop; and, again, that of the land favorable for the ordinary crops one-half should alternate with the other half, century in and out, in fields and forests. This rule may not apply to the grass-covered prairies of the Rocky Mountain slope or the Siberian steppes, but it certainly applies to the greater part of Europe and our Atlantic states.

The point that I would make is that the state weather services must so determine the average climate of each part of the state as to assist the economist or the state forester in selecting from all over the world the most valuable trees that can be introduced into each locality. Under the stimulus of the Division of Forestry in the Department of Agriculture, special efforts have been made in experimental tree planting on the western plains. In a recent report[1] by Charles A. Keffer, Assistant Chief of the Division of Forestry, he says:

[1] U. S. Dept. of Agric., Forestry Division, Bull. No. 18, 1898.

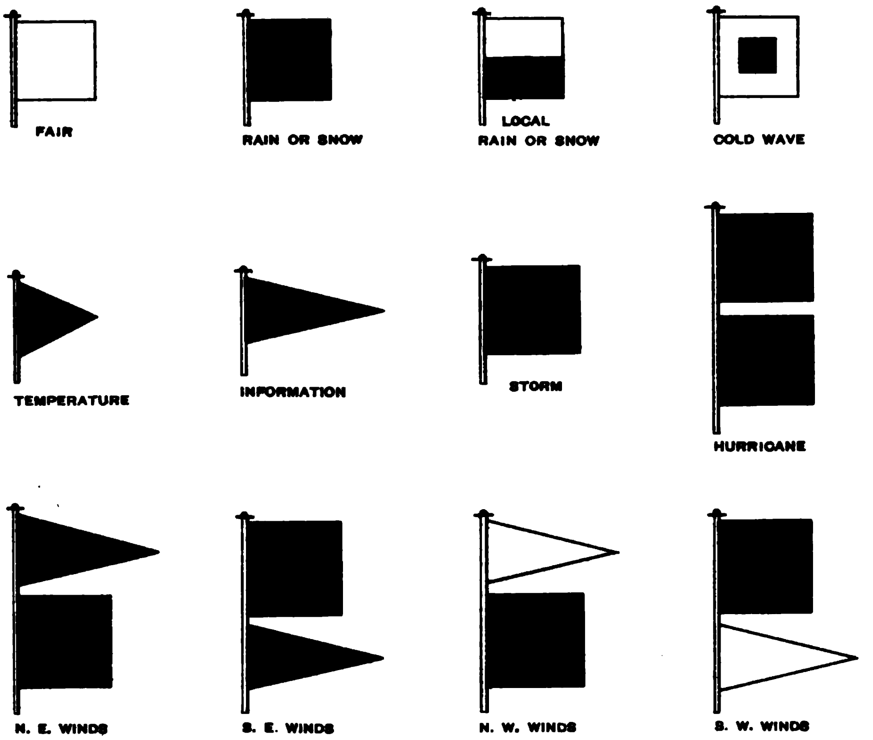
"In common with all plant life, trees require a certain amount of heat, light and moisture for their development. These elements are so interdependent in their effect upon tree growth that it is almost impossible to consider one without keeping in mind the influence which the other two are constantly exerting. Thus, if we discuss the effect of heat upon tree growth, we are at once reminded that the action of heat and light are inseparable and that the results upon the same species in a moist and a dry region are quite different. It must be remembered that these elements are never disassociated in their influence on plant growth.

"Most trees have a wide range of endurance of heat and moisture, but for each there is an ascertainable degree of heat, and, presumably, of moisture and light, at which it grows best. In tree culture the character of the soil is important principally in so far as it affects the amount of moisture and heat available for the trees. And the lay of the land or exposure is also to be considered principally with reference to heat, light and moisture."

The rest of this important paper gives many details and examples illustrating the general propositions here laid down; it gives also the results of many experiments, both successful and unsuccessful, in the cultivation of trees of all kinds. At every point appeals are made to the data furnished by the state weather services and the agricultural colleges, leaving no doubt that we have here an important field of coöperation for these two institutions in Maryland.

Experimental tree planting, with a view to the reforestation of portions of the country, involves a careful attention to climatic details and the condition of the soil. To a slight extent the forest reacts upon the general atmosphere, and may be said to affect the general climatology. Certainly the climate beneath a forest, or even in a thin grove of trees, is quite different from what it would be at the same spot if the trees were absent.

A state weather service may well devote considerable attention to the investigation of the relation between heat, moisture and light on the one hand, and the development of trees on the other, remembering that the extremes of heat and cold, drought and moisture, to



EXPLANATION OF THE SIGNAL FLAGS
USED AT
WEATHER BUREAU DISPLAY STATIONS.

FAIR SIGNAL. The White Flag alone indicates fair weather, stationary temperature.

RAIN OR SNOW SIGNAL. The Blue Flag alone indicates rain or snow, stationary temperature.

LOCAL RAIN OR SNOW SIGNAL. The White and Blue Flag indicates local rain or snow, stationary temperature.

COLD WAVE SIGNAL. The White Flag with Black Center indicates sudden fall in temperature, usually accompanied by stormy weather.

TEMPERATURE SIGNAL. The Black Pennant above indicates warmer weather of the type represented by the lower flag; below, cooler weather of the type represented by the upper flag.

INFORMATION SIGNAL. The Red Pennant indicates that the local displayman has received information of a storm covering a limited area, dangerous only for vessels bound for certain points.

STORM SIGNAL. The Red Flag with Black Center indicates that a storm of marked violence is expected.

HURRICANE SIGNAL. Two Storm Signals one above the other indicate the expected approach of a tropical hurricane or a severe and dangerous storm from the interior.

WIND SIGNAL. Pennants with the Storm Signal indicate the direction of the wind; red, easterly, from northeast to south; white, westerly, from southwest to north. The Pennant above the flag indicates that the wind is expected to blow from the northerly quadrants; below, from the southerly quadrants.

A. Hoen & Co. Lith. Baltimore.

which trees are subjected will probably decide as to their growth and prosperity in any location. The pamphlet by Mr. Keffer, above quoted, gives several instances of trees that are dwafed in northern climates but flourish in warmer zones; thus the Russian mulberry, which is little more than a shrub in South Dakota, where it is always "killed back" in cold winters, becomes a good-sized tree in the Arkansas Valley. In general, too much heat without moisture may also have a dwarfing tendency. The relation that determines the amounts of heat, light and moisture, conducive to the best growth of any plant is, undoubtedly, very complex. The wind and the soil must also be considered. Success in tree planting will depend largely upon the use of one kind of plant as a nurse for another kind, especially as a means of collecting snow in winter for the protection of the roots and as a means of making a cooling shade over the roots in the summer. The snow covering, therefore, is an important consideration; many plants are preserved among the hills of Western Maryland by the kindly action of the snow.

The State Weather Service has, therefore, from this point of view, a double incentive to obtain from all possible points in the state a record of the snowfall and especially of the snow lying on the ground, as a climatic datum that will eventually be of value to foresters.

I may venture the suggestion that the *Manna Tamarisk*, and other varieties of this beautiful genus of trees from Asia, which are at home in a saline soil, might well be acclimated on the shores and islands of Chesapeake Bay.

Weeds.

Nothing is more annoying to the farmer than the spread and growth of weeds. The reports of the agricultural experiment stations, showing how the common weeds are spread over the country, give special prominence to the wind as the agent; thus, in Kansas, Mr. Hitchcock[1] says:

"Almost all of our introduced weeds have come from the East and are spreading westward. A few of our plants are spreading eastward. Some of the plants break off just above the ground

[1] Kansas Exp. Sta., Bull. No. 80.

when ripe and are rolled along by the wind, others allow only the seed-bearing portion to fall off at maturity and be carried by the wind. In other cases the seeds are sticky when wet and adhere to dead leaves that are borne about by the wind. Some small seeds are blown long distances with the dust of high winds in dry weather."

The study of the distribution of weeds or other plants in Maryland will afford many illustrations of the influence of the wind and moisture. As this state has been settled for two hundred and fifty years, it may, perhaps, be said that the winds which blow at the proper season of the year have already accomplished all that they can do in the distribution of any special plant, so that the regions not yet reached may remain free for years to come. But a new weed is liable to be introduced at any time, and then the climatologist must be consulted as to its probable direction of spread by winds that prevail when its seeds are ripe.

Wind and Windmills.

The farmer and the manufacturer, as well as the majority of large householders, are learning to make daily use of the windmill, principally as a means of pumping water to any required height, but also as a source of power for doing any other kind of work that may be needed. In regions where the wind is very irregular the water pumped up by the windmill may, by its subsequent fall, be used as a source of steady power for doing work. The mechanical devices for utilizing either the wind pressure or the waterfall directly in the daily operations of the farm and the household are innumerable and are rapidly increasing. Nothing marks the progress of civilization and the prosperity of a community more surely than the use of these ingenious contrivances for avoiding the more expensive labor of men and animals. The Maryland State Weather Service could not do a more useful piece of work than to carry out what might be called a survey of the wind and waterpower, including the rainfall power throughout the state. It is frequently said that Niagara, or the flow of water over the many rapids and falls of the Potomac, represent a vast amount of power that is unutilized; but it is equally true that

the rain flowing down our mountain sides, the rivulets, and the wind that blows over the hill-tops, also represent a reservoir of power upon which very little draught has as yet been made. We have still to imitate Holland in the use of the windmill, and Switzerland in the use of her little waterfalls. The distinguished meteorologist, William Ferrel, tells us in his autobiography how busy his parents were, when he was a child, in mastering the intricacies of a successful watermill on some small stream in Pennsylvania. We need the development of mechanical genius in every state. A school of manual training as subordinate to the physical laboratories of our higher educational institutions would be a boon to the state of Maryland. Already efforts have been made in this direction by other states, notably Massachusetts, New York, Pennsylvania, Iowa and Wisconsin. Professor W. S. Aldrich, of the Geological Survey of West Virginia, has done much to bring about in that state the establishment of that engineering experiment station that is precisely what Maryland also needs in the further development of her internal resources. A project so intimately related to the duties of the State Weather Service may well be encouraged by it. In this connection I may remark that Prof. F. H. King, of the Agricultural Experiment Station at Madison, Wis., has recently published a bulletin showing that the amount of work done in one year by a 16-foot geared windmill at that place is equivalent to that done by an engine of 2 horse-power working fourteen hours per day, or a 4 horse-power engine working seven hours per day. As the space occupied by such a windmill and its tower is scarcely twenty feet square one may easily calculate the horse-power of the wind over the whole area of Wisconsin. Similar data for Maryland may be determined by its meteorological reports.

Climate and Roads.

The weathering or disintegration of rocks by the steady action of the climate has been made the subject of an important treatise[1] by G. P. Merrill of the National Museum. By this process the soil is formed in which our plants must grow. The character of the soil depends upon the weather as much as it does upon the rocks that are

[1] Rocks, Rock-weathering and Soils. Macmillan, New York, 1887.

being disintegrated. In dry and windy regions the finer particles of the soil may be blown entirely away by the wind, only to settle down in some quieter region and become aggregated into the rich loess formations. In a climate with moderate rains the finer particles are simply packed all the tighter among the coarser particles of the soil. In a climate of violent rains both fine and coarse particles are washed away, but may again find a resting place in the lowlands or as silt at the bottom of a lake. A covering of leaves or grass or bushes and trees deadens the fall of the large drops and preserves the surface from washing. We may leave it to the special student of soils to go further into this important subject; he will possibly be able to advise the farmer as to the best method of altering the texture of his soil so as to enable it to hold water in the manner needed for the growth of crops. He will explain how the soil depends on the atmosphere and show how to prevent its deterioration.

One of the most important items to the farmer is the quality of the roads or pathways to market; in fact, every form of transportation, whether of heavy freight or of light goods, whether of individuals or of the mails, is wholly controlled by the character of the roadbed and its light or heavy grades.

In the springtime the rich black loam of our Western States, as well as that of the Russian steppes, is a sticky mud that seriously and sometimes completely interrupts ordinary travel by wagon. In October, according to a quotation by Mr. R. De C. Ward from a recent work on Russia, when the first frosts have thawed and the first snows melted, the Government postal service is stopped, labor contracts are off, and the keepers of stages are freed from their usual obligations.

In the early settlement of the United States the progress of immigration, the development of agriculture, the price of land, the isolation of the farmer's life, and the sale of crops, all were guided and limited by the means of transportation. As canals and railroads and steamboats were developed, man triumphed over natural obstacles; at the present time the electric motor and the bicycle give us still greater advantages. But all these improvements in the machinery of trans-

portation involve a corresponding improvement in the character of the road and roadbed. No matter whether the roads be of dirt or macadam, Belgian blocks or a railroad bed, their relative excellence depends upon the character as to weathering of the soil and the stone of which they are made. The national roads built between 1790 and 1840 are still used, and a study of their present condition will give much information as to the influence of the climate on these roads. It is proper, therefore, that the meteorologist, geologist and mineralogist be consulted by the engineer who constructs a road if he would attain the best results with the greatest economy.

Damage from Lightning.

Insurance against the loss of life and property by lightning is at present carried on in this country on a large scale, but the prices paid as premiums are apparently too severe on the policyholder. When the statistics of loss have been collected and studied with proper regard to the laws of probability, it will undoubtedly be seen that insurance rates much lower than those now charged should be profitable to the companies and would encourage many more to insure. But prevention is better than insurance. May it not cost less to prevent injury than to pay for it? Protection against lightning is a subject for most thoughtful consideration. I see no reason why some famous electricians should not solve the problem perfectly and economically. The physical laboratories and the State Weather Service may work together in handling this problem, which is as definite as it is practical and important and which should stimulate the greatest talent. One fine work, that of Oliver Lodge, on "Lightning Conductors and Lightning Guards," has been written, but there is more to be done.

The efforts of the U. S. Weather Bureau to secure simultaneous meteorological records from great altitudes by the use of kites at many stations, lately received a slight check that brought us face to face with a new problem, one that the Maryland physicists may also attempt to solve. Our kites are controlled by a kite line of steel wire unrolled from a powerful reel. When a mile or more of such wire stretches away up toward the clouds it becomes an admirable

conductor for electricity, and, on four occasions, long before a dangerous flash of lightning occurred, even in a clear sky, the wire disappeared in a wreath of smoke.

The loss occasioned by lightning depends, of course, upon the special value of the object that it strikes; it may be a load of hay or a museum of the rarest works of art. The money spent to protect from injurious strokes should be in proportion to the value of the property. The chance of being struck is about the same for all, but the magnitudes of the resulting disasters differ immensely, and it behooves those whose valuable properties are in danger to consult the best authorities as to their protection.

Perhaps one of the most curious connections between meteorology and geology is found in the proposed explanation of many a mysterious lightning stroke as given by Lieutenant-Colonel J. T. Bicknell.[1] A building or tree or passing traveler may be standing on a series of subterranean strata having, relatively speaking, very different conducting powers for electricity. These constitute a so-called electric condenser, and the man standing on it is in danger of a severe stroke when a flash that would otherwise be harmless passes near him, and the invisible condenser beneath him. We may add that, so far as at present known, complete protection is secured only in proportion to the extent with which the object is surrounded by a sheathing or framework of metal. Heavy telegraph wire passing in several directions over the roof of a house or barn, around the corners and then down in several places to a good connection with the ground, meets most of the requirements of the case. A broad band is better than a solid wire or a hollow-tube containing this same weight of metal. Probably the tin roofs and waterspouts of buildings in cities, when wet with water, contribute not a little to their protection from lightning. In all important cases the theoretical electrician should be consulted and proper electrical tests be made at least once a year in dry, summer weather, in order to ascertain the exact condition of the ground connections.

The steady but feeble electrical discharges going on from rocks

[1] See Lodge, "Lightning Conductors," etc., 1892, p. 227.

and trees on the sides of mountains are supposed by some to greatly affect the character of the vegetation, but this is not yet well established. Such discharges must, however, facilitate the evaporation of moisture and thus have an indirect effect. It has even been believed that the repeated discharges must produce some permanent magnetism in the rocks of the earth's crust, but this again awaits further investigation and is not a very plausible hypothesis.

The popular error that lightning causes milk to turn sour in the dairy has already been exploded and the true explanation has been found. In this, as in all similar cases, no sooner do we truly understand nature than we are able to find a remedy for the trouble. Ignorance is exceedingly expensive. Every step in the progress of knowledge can be made of practical value to man in alleviating suffering, lessening labor and elevating his position.

Hygiene and Drinking Water.

The water that is used throughout the world for drinking and household purposes comes indirectly from the rain or snow; but it is usually considered desirable that the rain should penetrate the earth and flow thence in clear springs. The water that is thus filtered through the soil partakes to a certain extent of some of its characteristics. Thus the analyses of the drinking water taken from springs and rivers show a considerable addition of earthy salts dissolved by the rainwater, and this quantity increases in proportion to the fine texture of the soil and the slowness of the percolation and the acids and alkalies in the rainwater itself.

But the soils themselves depend for their own chemical composition upon the rocks from which they have been derived. The relations between geological formations and the chemical composition of the water we drink are quite definite. The analyses of the French soils have shown that granitic soils are generally poor in phosphoric acid and rich in potash. The Lias soils are remarkably rich in phosphoric acid and potash. The calcareous are very fertile, less tenacious than the preceding, and, of course, consist of carbon and lime. The soils of the Oxford formation are strong, rich, clayey, calcareous. The ferruginous clays and sands are very poor soils, extremely deficient in

lime and phosphoric acid. Each of these soils gives rise to its own peculiar and specific type of spring water. Invalids are advised to try one or the other, according to the nature of their disease. The steady flow of the water must depend largely on the seasonal rainfall and the internal capacity of the soil and strata. A survey of the aqueous resources of the state from a geological and meteorological and hygienic point of view would probably result in discovering many valuable waters overlooked and forgotten hitherto.

Palæo-climatology.

The study of geology includes palæontology and the general history of the process by which the most ancient igneous and metamorphic rocks have become converted under atmospheric influences into stratified and valuable rocks, gravels and sands and innumerable varieties of surface soils. Geology is primarily a study of the influence of the overlying atmosphere upon the earth beneath. It is, therefore, an essential part of this study to understand the climates and the changes in climate that have prevailed since the earth began its annual course around the sun and its diurnal revolution around its axis. The study of modern climates must be considered by the geologists as simply an introduction to the equally important study of ancient climates and the work done by them. The fact that these palæontological climates have long since finished their work and disappeared does not diminish the importance of the study, for what was going on under a specific climate in ancient days, at a given locality, may now be going on under the same climate in some other locality. Cuvier, von Waltershausen, Whitney and other geologists have attempted to describe the characteristics of some of these ancient climates. Especial interest has gathered about the Glacial period, the Carboniferous era and the Archean epoch, but we cannot restore these climates from a mere knowledge of the species of plants and animals that flourished at any time. We must know the general distribution of land and water, the altitude of the land, the gaseous and aqueous contents of the air. With these data we might, theoretically, reconstruct the climate with a moderate degree of success.

APPARATUS AND METHODS.

THERMOMETERS.

The thermometer is used to determine the temperature of any substance at any place at a specific time. The most accurate and so-called standard thermometer utilizes the expansion and contraction of some simple gas, such as nitrogen or hydrogen. A large bulb filled with gas is so arranged that the expansion of the gas with heat, or its contraction with cold, is counterbalanced by the pressure of a column of mercury. The height of this column is the measure of the gaseous pressure corresponding to the temperature inside the bulb. The errors of the ordinary mercurial and spirit thermometers are found by comparison with the standard gas thermometer, and they are therefore subject to small corrections which vary from point to point along the scale, and must be applied in order to obtain the correct temperature. When we apply the mercurial thermometer to the measurement of the temperature of water we are confronted by the consideration that the water is liable to be arranged in strata, cold at the bottom and warm on top, and, again, that water is a very poor conductor of heat. In order, therefore, to obtain the correct average temperature, we not only stir the water up into a thorough mixture, but also cause it to flow rapidly past the bulb of the thermometer, so that conduction may be replaced by convection, and the temperature of the bulb be brought as rapidly as possible down to the average temperature of the water. These two processes of mixture and convection are easily accomplished by simply stirring the thermometer rapidly in the water.

It is generally assumed that the graduated stem of the thermometer has the same temperature as that of the bulb, but if there is known to be an appreciable difference in this respect a slight correction has to be applied.

When the thermometer is applied to the determination of the temperature of the air, the same methods of mixture by stirring must be followed, but in addition to this comes in a still more important consideration, viz., the question of radiation and absorption of heat.

A thermometer bulb that is covered with a delicate coating of lamp-black absorbs 90 per cent. of all the radiation that falls upon it, and, by converting this into heat, the temperature of the bulb is raised much higher than that of a thermometer without lamp-black. An ordinary plain glass bulb absorbs 20 per cent. or 15 per cent.; a polished silver bulb absorbs only 5 per cent. or 10 per cent. of the radiant energy that falls upon it. On the other hand, these different styles of surface-covering radiate their own heat outwards with an ease that is directly proportional to their absorbing powers. The radiating powers may be approximately stated as follows: lamp-black, 90 per cent.; plain glass, 20 per cent.; polished silver, 5 per cent. Now the relative temperatures of thermometers with such bulbs will depend upon the difference between the heat absorbed and the heat that is given out by radiation, and this difference depends upon the relative temperature of the bulb and its external surroundings, such as the ground, the clouds, walls, houses, trees, etc. In order to obtain the true temperature of the air, the thermometers should, therefore, be surrounded by an enclosure whose temperature is that of the air itself. This condition is very difficult to fulfill. The best approximation is attained by placing around the thermometer a light shelter of open slats, or something that will allow the wind to blow through with great freedom but will cut off the heat of the direct solar radiation or the radiation from hot sandy soil or from the reflection from the walls of buildings, and will also prevent the thermometer from losing its own heat by radiation at night-time to the clear sky. Within such a shelter the temperature of the air and the thermometer will not differ more than a few tenths of a degree Fahrenheit from the average temperature of the wind that is blowing through, provided the wind has a velocity of over five miles per hour. But, for lighter winds and calms, and especially in the full sunshine, the error may be larger. In order to diminish the effect of any noxious radiation, the thermometers used in the Weather Bureau are mounted upon a small axis and rotated rapidly within the shelter so as to increase the convection, and thereby, as it were, dilute and overcome the influence of radiation. At each station this shelter is established high above the

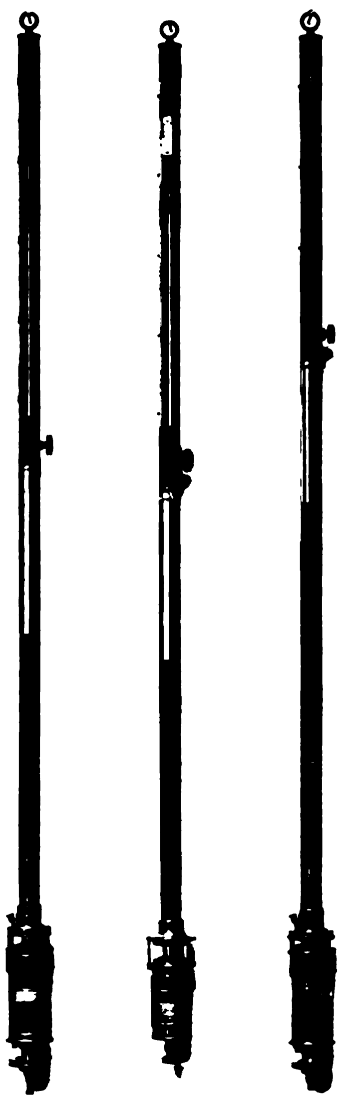


FIG. 1.

FIG. 2.

FIG. 1.—MERCURIAL BAROMETER.

FIG. 2.—SLING PSYCHROMETER.

roof on some high building, Fig. 27, where it is freely exposed to the wind from every direction. The temperatures desired by the student of storms in order to predict their movements are the temperatures of a large mass of air high above the ground and not the temperatures of the quiet air near the ground. The study of the latter belongs to local climatology in its most restricted sense.

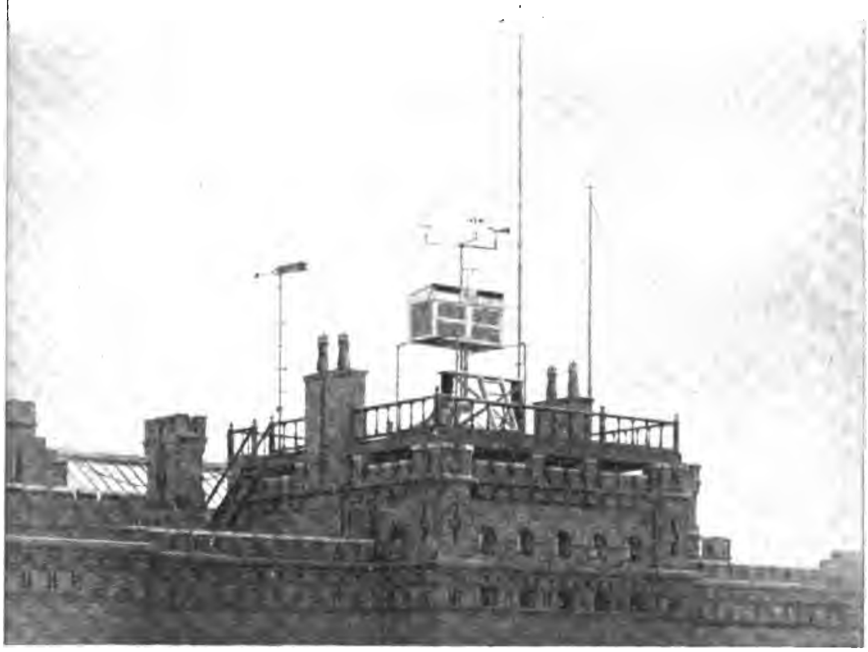


FIG. 27.—Top of the U. S. Weather Bureau building, Washington, D. C.

Even without a stationary shelter one may get the temperature of the air with sufficient accuracy if he hang his thermometer on a short chain and whirl it very rapidly through the air for two or three minutes. This is the portable whirled or sling thermometer, as shown in Plate XXVII, Fig. 2.

In order to determine the range of temperature during each day, maximum and minimum thermometers are used. The reader will

perceive these in their proper positions in Fig. 28. Both of these thermometers automatically register their highest and lowest temperatures respectively.

The maximum thermometer has the capillary bore of the tube somewhat constricted just above the bulb so that mercury that has once been pushed up past this point cannot easily slide back. When the temperature is rising the mercury in the bulb, little by little, is forced up past the constriction, but when the temperature is falling the upper column remains intact. After the maximum temperature has been read off the observer sets the thermometer for the next day's record by holding it in his hand and whirling it around so that the

FIG. 28.—Maximum and minimum thermometers.

centrifugal force drives the upper column back into the bulb until the latter is filled up to the constriction.

The minimum thermometer has its bulb and lower part of the tube filled with alcohol. Within this alcohol is a slender piece of black glass, the upper end of which touches the curved top of the column of alcohol. As the alcohol descends in the column it draws the glass index downwards, but when the lowest temperature has been reached and the alcohol begins to ascend the index is left resting in its lowest position.

The maximum and minimum thermometers should be read every morning and evening and then set back in order to get the correct record for the next twelve hours. Some persons read and set only once a day; of course, this gives the daily maximum and minimum, but does not suffice to show quite close enough just when they

occurred. It can easily happen that the maximum temperature of a day is due, not to sunshine, but to a blast of hot wind. Again, the minimum temperature may be due, not to radiation at night-time, but to a blast of cold wind. In general, human health depends largely upon sudden changes from hot to cold weather or vice versa, and the frequency and importance of such changes are best revealed by the record of maximum and minimum temperatures for each successive twelve hours.

The temperature of the soil or of wells may be determined by thermometers whose bulbs are placed at the proper depths and whose stems are long enough to bring the necessary graduation marks above the surface of the ground. The bulbs are kept in touch with the adjacent earth by dipping into a metallic cup holding water or mercury, but they are protected from the pressure of the soil by the perforated metal tube that surrounds them. The depths adopted by Prof. Milton Whitney are 1, 3, 6, 9, 12, 24, 36, 48 inches respectively. Electrical methods of observing and recording temperatures in distant places, especially those of the soil, have been devised by Prof. Whitney and his assistant, Dr. Lyman S. Briggs, and have been described in a bulletin[1] just published by the Division of Soils.

Barometers.

The pressure of the atmosphere is measured by the barometer. The etymology of this latter word would indicate that the barometer measures weight, and it is true that the weight of the atmosphere above us is that which causes the air to press down upon us; but the air is an elastic fluid; if we push a piston into a cylinder, forcing the air vertically downwards, we produce a pressure, not merely downward on the bottom of the cylinder, but equally upward on the piston and horizontally in all directions against the inside of the cylinder. Just so with the atmosphere, every cubic inch of air is compressed on all sides by the superincumbent pressure and is itself pressing outwards in all directions in order to counterbalance this pressure. The barometer measures this elastic pressure, no matter whether it is due to weight or to heat or to motion.

[1] U. S. Dept. of Agric., Division of Soils, Bull. No. 7, 1897.

The mercurial barometer consists of a glass tube 33 to 36 inches long, whose top is hermetically closed and whose lower end opens into a cup or so-called cistern of mercury. Just as the pressure of the atmosphere pushes the water in a well up through the bore of the pump when the piston is raised, so it pushes the mercury in the cistern up the vacuous glass tube of the barometer. The complete instrument is shown in Plate XXVII, Fig. 1, where it will be seen that the glass tube is placed inside of a brass tube, partly for protection and partly for convenience in determining the height of the column of mercury. The distance from the surface of the mercury in the cistern up to the top of the column is about thirty inches in ordinary weather at sea level, but it may rise to thirty-one inches in our clearest cold weather of winter, or it may fall to twenty-eight inches in the center of a severe storm.

These variations in the pressure of the free atmosphere are undoubtedly brought about by several processes that are going on in the air. A remarkably high pressure means that an area of denser air is pushing under some lighter air, lifting it up and pushing it out of the way so that, temporarily, there is a greater mass of air above us and pressing down upon us. But this abnormal pressure soon diminishes as the denser air spreads out broadly over the globe. At other times the barometer begins to fall and pressure diminishes while winds and rain or snow increase. This diminution is partly due to a diminution in the quantity of air above us, but this is quite insignificant in comparison with the influence of the winds. A small region of low pressure is sure to be surrounded by a very symmetrical system of winds, such as we perceive on the weather maps, Figures 21-26. In general, a strong wind does not preserve its course in a straight line for any length of time; it is in the northern hemisphere, perpetually pushing away toward the right hand, so that when we have southerly winds to the east of a station and northerly winds to the west, we are sure to find low pressure at the station itself, since each of the winds pulls away from the station and produces a low pressure.

The mercurial barometer requires great care in transportation, but other forms have been made that are easily transportable. This is

especially true of the aneroid barometer, first invented by Vidi, but now frequently manufactured according to the method invented by Bourdon. The Vidi aneroid consists of a hollow, flat cylinder or box having strong cylindrical sides but delicate, corrugated circular ends. The air having been exhausted from the interior of this cylinder, it becomes a so-called " vacuum box," and the corrugated ends would be pressed inward until they touch each other were not a strong steel spring made to counteract this tendency. As the pressure of the atmosphere varies, these springs yield a little to the outside pressure, and an index needle moves over the graduated scale to show the corresponding changes in pressure.

The Bourdon aneroid has no corrugated vacuum box, but, instead of this, a box in the shape of a ring having an ellipsoidal section. As the pressure upon this vacuum ring increases or diminishes, the ring changes its curvature and the index needle moves correspondingly.

In the mercurial barometer the weight of a column of mercury counterbalances the elastic pressure of the atmosphere, but in the aneroid barometer the elasticity of the steel spring or the vacuum ring counterbalances that pressure. The aneroid may be carried to any latitude or any altitude, and, provided its temperature be kept uniform, its indications will depend only on the actual change in pressure. If, on the other hand, the mercurial barometer be carried to other localities, even though its temperature be kept the same, still its indications will vary, not only with pressure, but with the force of gravity, which is that which gives weight to the mercury. In spite of the simplicity of the aneroid, it has not yet been made sufficiently accurate to replace the mercurial barometer.

It is quite common to find a cheap instrument offered for sale which is called a barometer or baroscope, although it has no proper claim to that title. This consists of a short glass vial containing a liquid in which camphor is dissolved and which changes its appearance from time to time. These changes depend upon temperature, not upon pressure, and a careful record of the changes will show that they cannot be used any better than a thermometer for predicting the weather.

It would be interesting to keep a record of the fall of ice, namely, sleet or hail, as distinguished from the fall of rain or snow, but no satisfactory hail-gauge has as yet been described. Possibly, it might

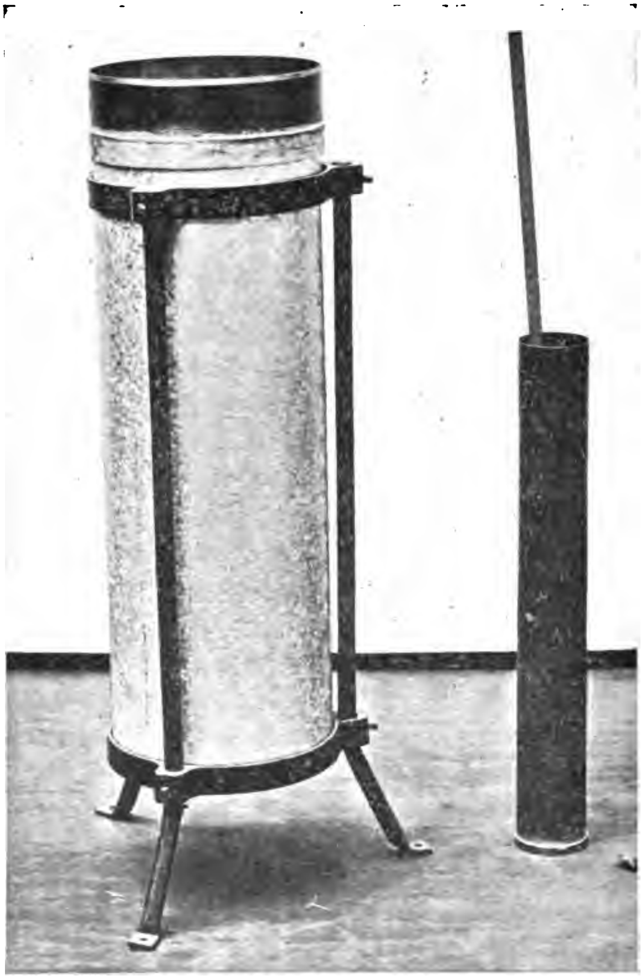


FIG. 29.—Rain-gauge.

be well for some observer to experiment with a basket or bag, having a circular hoop to keep the mouth open and a bottom so porous as to allow the rain to quietly pass through while retaining all the hail.

TIPPING-BUCKET RAIN GAUGE.

The accuracy of the measurements of rain was for a long time supposed to depend upon the precision with which we knew the ratio between the aperture of the mouth of the gauge and the section of the small measuring cylinder. But it now has been abundantly proven that the most important matter is the influence of the wind at the mouth of the gauge. When we consider the movement of the wind around an obstacle such as the rain-gauge, we shall find that it blows over the top in such a way as to carry much of the lighter particles of snow and rain entirely past the gauge; many others which are carried into the gauge temporarily are almost immediately whirled out again by the little eddies formed within the mouth of the gauge. Apparently, a much higher accuracy would be attained if we could prevent all these eddies and special currents around the gauge. The earliest method of attaining this object consisted in setting the gauge up in a shallow pit so that the mouth of the gauge should be on a level with the surrounding ground. This is called the "standard pit gauge." Professor Joseph Henry advised the early Smithsonian observers to use a gauge having a horizontal circular rim of sheet-iron extending horizontally for several inches in all directions just below the rim of the gauge. Professor Nipher of St. Louis, constructed an umbelliform attachment of wire screen surrounding the gauge in such a way as to ward off and break up the force of strong winds so that the mouth of the gauge was in a small region of comparative calm. Professor Börnstein, of the School of Agriculture in Berlin, experimented with ordinary gauges at heights of 1 to 5 feet above ground, placed within a small enclosure of boards or slats so nailed to the upright posts as to break the force of the wind. Hellmann, also in Berlin, placed gauges at the center of a depressed roof so that the walls of the building acted as ramparts to break the force of the wind. All these methods of protection agree in showing that correct rainfall can only be obtained when the wind effect is nullified or measured and allowed for. In order to measure it and make the proper allowance, I have shown that gauges placed at different heights above the ground in the free air give smaller rainfalls in proportion to the velocity of the wind at their respective

heights, and that the difference between two or more such gauges gives the necessary data for obtaining the true rainfall. It is very desirable not to alter the location or otherwise break the continuity of old series of rainfall measurements; therefore, I would urge that it is easy to increase the accuracy of the newer measurements and obtain a co-efficient for correcting the older ones by establishing near any observer's gauge one or more additional ones at different heights, so as to determine the wind effect.

All our discussions concerning the influence of forests on rainfall, the secular changes in climate, the relation between rainfall and the regimen of a great river system must depend upon the absolute accuracy of our rainfall data. The influence of the wind upon unprotected rain-gauges is larger than all other sources of error combined. So long as we cannot properly allow for this we have no right to reject the record of a special rain-gauge, simply because it appears to be discrepant from its neighbors, but it must be included in a common average for a limited area.

Anemometers.

The velocity of the wind in miles per hour is a datum preferred by meteorologists to the pressure of the wind in pounds to the square foot; but the latter is that about which navigators, engineers and builders most frequently inquire. Now, the pressure evidently depends upon not only the size, but the shape of the obstacle and the density of the moving mass of air. In fact, during a driving rainstorm, the horizontal movement of the rain is added to that of the wind and materially increases its pushing force. The push of a fifty-mile gale against a mainsail of 2,500 square feet area is probably much less than the pressure of the same wind against a surface of 2,500 square feet of ropes, masts and spars; this is due to the cylindrical shape of the latter as compared with the flat shape of the former. The engineer cannot determine even approximately the pressure against an obstacle until he carefully considers the size and shape; therefore engineering reasons combine with meteorological reasons to confirm the general practice of measuring and publishing only the approximate velocity of the wind, leaving it for each individual to

THE ROBINSON ANEMOMETER.

deduce the pressure on any area in which he is interested. Formerly there was a tendency to use pressure anemometers, but at present the Robinson anemometer or the Richard "girouette" is used, except in Russia. The Robinson anemometer is shown in Plate XXIX, and as usually mounted in Fig. 29. It consists essentially of a vertical steel spindle to which there are attached four horizontal arms, each of which carries at its extremity a hollow hemispherical shell or cup. The excess of pressure of the wind against the concave side of the cup over that on the convex side drives the arms and spindle around at a rate that can be measured by means of a counter. If the wind is very gusty its action upon the cups becomes very variable, and if the cups are too massive, that is to say, if the whole apparatus has too large a moment of inertia, then the recorded velocity of the wind will be decidedly larger than it should be. This correction for the inertia of the movable parts of the anemometer has been investigated by Professor Marvin. It may amount to 20 per cent. in the case of very gusty winds acting upon the rather heavy anemometers of the U. S. Weather Bureau type.

The mechanism of the spindle is so arranged that one hundred revolutions correspond approximately to a mile of wind, which is electrically recorded by a mark on the so-called "triple register" shown in Plate XXX, Fig. 2, which has graduations that correspond to minutes and hours. By counting the number of miles recorded in any five or ten minute space we can learn the velocity of the wind in miles per hour.

Wind Vanes.

The style of wind vane that has been in familiar use from ancient times is a single plane plate revolving about a vertical axis and forced by the wind to set itself in the direction from which the wind is blowing. Mr. G. E. Curtis, about 1886, made a study of the conditions under which an anemoscope should be most sensitive and point most steadily in the direction of the wind. He found that there were arguments in favor of a vane having a single piece facing the wind and an expanding tail at the rear. This form of wind vane had been advocated by Parrot in 1800, and had long been in use by the

U. S. Signal Service and the Weather Bureau. The tendency now is to make the vane rather shorter and smaller than formerly.

The wind vane must be placed as high as possible above all surrounding obstacles in order that there may be no local obstacle to produce eddies that will affect its direction. As it is also true that the anemometer must be placed high above local surroundings, it is considered preferable to combine both of the instruments on one staff, as shown in Fig. 29.

Observers sometimes substitute the direction of the motion of the lower clouds for that of the wind, under the mistaken idea that the cloud direction is more accurate or more important than the wind. Observations, however, have abundantly shown that the movement of the wind differs from that of the clouds and that, in fact, there is a general relation by virtue of which, as we ascend, the successive layers of clouds are found to be moving more and more to the right of the lowest winds. It is, therefore, conceived to be very important to record both the direction of the wind and the direction of the clouds in order that we may better determine the amount of this deviation to the right, which is evidently the effect of the rotation of the earth on its axis. This deviation has been determined for several stations, but more work still remains to be done.

SUNSHINE RECORDER.

In addition to the observer's personal observation of the proportion of clear sky covered by clouds, it is recognized that both for dynamic meteorology and for climatology we need more detailed records of the amount and intensity of sunshine. This latter factor belongs to the subject of actinometry, but the total duration of sunshine and its distribution from hour to hour is shown by some form of sunshine recorder. The Campbell recorder consists of a large glass or quartz globe which acts as a burning glass; behind it is placed a sheet of pasteboard or a block of wood and the record that is burned in by the concentrated solar rays gives a fair record of the amount of bright sunshine.

The two forms of this apparatus used by the U. S. Weather Bureau

FIG. 1 —JORDAN'S SUNSHINE RECORDER.
MARVIN'S SUNSHINE RECORDER.

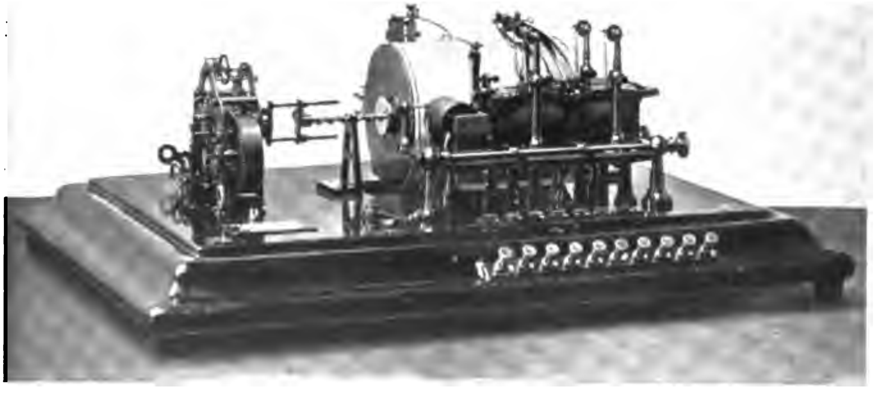


FIG. 2.—TRIPLE REGISTER.

make but little distinction in the various degrees of intensity of sunshine; they are, viz., the Jordan or photometric sunshine recorder, and the Marvin or thermometric sunshine recorder. In Jordan's instrument two small sheets of blue print paper are inserted into two hemi-cylinders of brass, in each of which there is a small bevelled aperture through which the sun's rays may pass. One cylinder is for the afternoon record, the other is for the morning. As the sun ascends from the horizon to the meridian the narrow beam that passes through the aperture makes a continuous line upon the prepared paper unless clouds intervene. A similar record is made on the afternoon paper as the sun descends. A permanent time scale showing each hour of the day is inscribed on the same prepared paper. At the end of a week or a month the paper is removed, the record is fixed chemically and then properly read off. The results of such readings, or the number of hours of sunshine, are given in tabular form regularly in the Monthly Weather Review. The instrument itself may be seen depicted in Plate XXX, Fig. 1a.

An apparatus that accomplishes nearly the same thing is shown in Plate XXX, Fig. 1b. This is known as Marvin's sunshine recorder. This instrument consists of a black bulb thermometer below, communicating with a bright bulb at the upper end of the same stem. By the difference in temperature of the two bulbs a bead of mercury is kept moving up and down the stem between them. When the temperature of the black bulb rises, as it does when the sun comes out from behind the clouds, the mercury index rises and as long as it maintains a certain position it forms the junction between two electrodes, allowing a current of electricity to pass and causing a record to be made of the fact that at this time the sun was shining with sufficient strength to produce this standard difference in temperature between the bright and black bulbs. When a cloud intervenes the black bulb temperature diminishes, the index falls, the circuit is broken and a new record is made to that effect.

A modification of Jordan's sunshine recorder has recently been suggested by Mr. Maring of the U. S. Weather Bureau.[1] In this

[1] See the Monthly Weather Review, 1897, p. 485.

instrument the cloudiness is recorded by the intensity of the photographic trace as usual, but simultaneously therewith is photographed the record of the varying height of the black bulb thermometer. As the latter thermometer is exposed to currents of air and to radiation from surrounding objects, this can be but a crude dynamic actinometer in which the ever-varying clouds become the screens and the rate of fall or rise in the thermometer may be read off from the record for every alternation of clear sky and cloud. This instrument contains, therefore, a good suggestion for further improvement in hopes that an actinometric method may be devised that shall give valuable results and allow of continuous self-registration.

The personal observations of cloudiness and sunshine show systematic differences from the records given by Jordan's and Marvin's sunshine recorders that have not yet been satisfactorily explained. Much data relative to this matter will be found in the Monthly Weather Review for 1894-98, and will well repay the study of those physicists who are inclined to devote themselves to meteorology.

ACTINOMETERS.

The object of the actinometer is to measure the total intensity of the solar radiation as received at any station; upon this depends the temperature of the ground, as well as of the air, and all the phenomena of animal and vegetable life. Many methods for the accomplishment of this purpose have been devised, beginning with those of Draper and Bunsen. During the past few years the detailed work on the individual lines of the spectrum done by Professor S. P. Langley with his bolometer, and the visual studies of the vapor lines made by Mr. L. E. Jewell with Rowland's spectroscope, have stimulated inquiry in this direction; owing to the expensive character of the apparatus, such work must always be carried on at fixed physical laboratories.

Actinometric measurements, summing up the total energy of the sunbeam, were for a long time made only by means of the Pouillet pyrheliometer or the analogous actinometer of Herschel. But as this instrument was delicate and its use rather tedious, it was eventually considered proper only for use of the experimental physicist for

meteorological work; it was replaced by the Arago-Davy actinometer or the so-called bright and black bulbs *in vacuo*, although this was known to be unsatisfactory, as it did not give comparable results at all places. It does not appear that a correct theory of the actinometer and a proper method of reducing the observations were available until Ferrel's investigation was published.[1] Since then the great advance made in our knowledge of actinometry has been summed up by the investigations of Professor O. Chwolson of St. Petersburg, published in Wild's *Repertorium für Meteorologie*, Vols. XV and

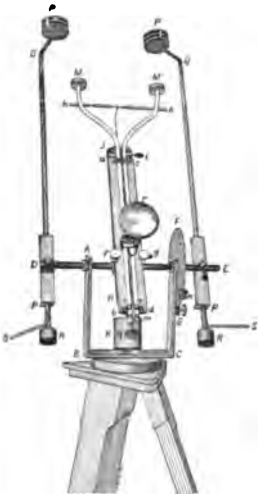


FIG. 30.—Chwolson Actinometer.

XVI. After reviewing the works already mentioned and those of Crova, Violle and Angström, he was able to show that with certain modification the apparatus of Angström and the so-called "dynamic method" would probably give the best results. Chwolson's apparatus and methods are briefly described at page 721, U. S. Weather Bureau Bulletin No. 11; in it two similar homogeneous black surfaces are exposed alternately to the solar radiation and then shaded from it. The rise and fall of temperature of each of the two bodies is measured by very delicate thermometers and forms the basis of two

[1] "Professional Papers of the Signal Service," No. XIII, Washington, 1884.

different methods of computation of the intensity of the sunshine at that moment and place.

For ordinary meteorological observers Chwolson recommends his pyrheliometer (see Fig. 30), in which the temperatures are measured by means of delicate thermometers, but for fundamental absolute work, he recommends his absolute actinometer, in which the temperatures are measured by an electric method. The method of use is quite similar for both instruments.

In the Paris *Comptes Rendus* for May, 1898, Crova described his new absolute actinometer, in which a disc of metal that is a very good conductor of heat, having a perfectly uniform and measured thickness and a large diameter, blackened on the front face, but polished on the opposite face, is exposed normally to the solar radiation. This is placed within a complete enclosure whose temperature is kept constant while the disc is protected from the currents of the surrounding air. The temperature of the disc, when shaded from the sun, is the same as that of its enclosure, but when the sun is suddenly allowed to shine upon it the temperature rises rapidly and is read off every thirty seconds. These readings enter into the formula for computing the thermal intensity of the incident beam of solar radiation. In the apparatus constructed by Crova this thermal intensity is determined to within the thousandth part of its own value. A complete determination requires about three minutes and consists of, first, a series of observations in the shade, then a series in the sunshine, and, finally, a second series in the shade. The lamp-black with which the metal disc is covered, when prepared according to Crova's method, has a uniform absorbing power of 98 per cent.

A self-registering actinometer giving a continuous record still remains the great desideratum in climatology. The Arago-Davy apparatus and, in fact, any other static system, lends itself easily to self-registration; but there has not yet been devised any satisfactory method of interpreting these records in standard calories. The newest apparatus devised in 1898 by Violle for high-balloon ascensions is the best that has yet been accomplished in this line, but probably is inferior to the standard dynamic methods of Pouillet, Herschel, Ang-

ström, Chwolson and Crova. The alternate screening and exposure of the absorbing plates in Chwolson's and Crova's methods, or of the bright and black bulbs of the Arago-Davy apparatus as done by me in 1883, might be automatically performed by clock-work in such a manner as to make the whole apparatus automatic and self-registering; but the calculation of the results of the record would demand heavy labor.

The dynamic method may be advantageously applied to the Arago-Davy actinometer. The black and bright bulbs *in vacuo* are sheltered from currents of air and surrounded by enclosures of uniform known temperature almost as perfectly as in Crova's absolute actinometer. If now we arrange screens so that these two thermometers may be observed under the influence of full sunshine, and of no sunshine alternately, we then obtain the same data that is used in the other dynamic methods. Unfortunately, the volume containing the records of the writer's first observations by this method in 1885 was lost in the fire of that year. This method was also recommended by me for trial at the observation of the Total Solar Eclipse of August, 1887, in Russia, and in May, 1883, in the Caroline Islands. The necessary apparatus is quite portable and inexpensive, and may be recommended to a large class of meteorological observers.

Another important class of actinometers measures the chemical action of the solar radiation, and some form of this apparatus may be invented that will be peculiarly appropriate to any special investigation. Sir John Herschel seems to have been the first to propose the use of sensitized paper in an actinograph. Just as each wave length has its own special power of acting upon the chemicals of the ordinary photographic plates, so also it has its own power to produce other decompositions. Becquerel used a mixture of oxalate of ammonia and bichloride of mercury, which is decomposed in sunshine with the evolution of no carbonic acid gas, but the formation of a white precipitate of the protochloride of mercury. Marchand adopted a modification of one suggested by Draper, viz., a solution of oxalic acid and the perchloride of iron. By the action of light the perchloride of iron is reduced to the protochloride, some hydro-

chloric acid is set free and the oxalic acid is transformed into carbonic acid gas which is set free and measured, while the liquid remains colorless. The volume of the gas is from 13 to 17 times that of the liquid. Regular observations have been made daily with this apparatus at Fécamp on the French coast since December, 1868. As in all similar work, Marchand's observations also show a great variation in the chemical transparency of that which appears to the eye as a pure, clear sky. The action of sunlight on a mixture of chlorine and hydrogen, forcing these to unite slowly into hydrochloric acid, was used by Bunsen and Roscoe in their photo-chemical researches. Apparently, many other chemical reactions are equally applicable to the measurement of the influence of the solar rays. We may make valuable measurements, no matter whether we observe optical or thermal, chemical or electrical effects. We must, however, be careful not to confuse matters by assuming that any one variety of measures can be certainly compared with another. The specific effect of a beam of light undoubtedly depends upon the intensity of certain specific wave-lengths; those that effect the thermometer, as heat, do not necessarily affect the photographic plates, and those that produce a great effect in the decomposition of one chemical may have little or no effect upon another. If, as seems likely, all (or perhaps 98 per cent.) of the energy in a beam of sunshine is equally absorbed by the black-bulb thermometer, then of course the thermometric method is that best adapted to tell us about periodical changes in the solar radiation or in the atmospheric absorption. But if we wish to know specifically the differences in the influence of sunshine upon the growth of different plants, we must employ appropriate chemical processes in our actinometer.

Nephoscopes.

In order to observe the apparent altitude of a cloud and the direction of its apparent motion, numerous devices have been constructed, the most elegant and useful of which for ordinary station use is that known as the Marvin nephoscope, which is illustrated in Plate XXXI, Fig. 2. A general description of many forms of nepho-

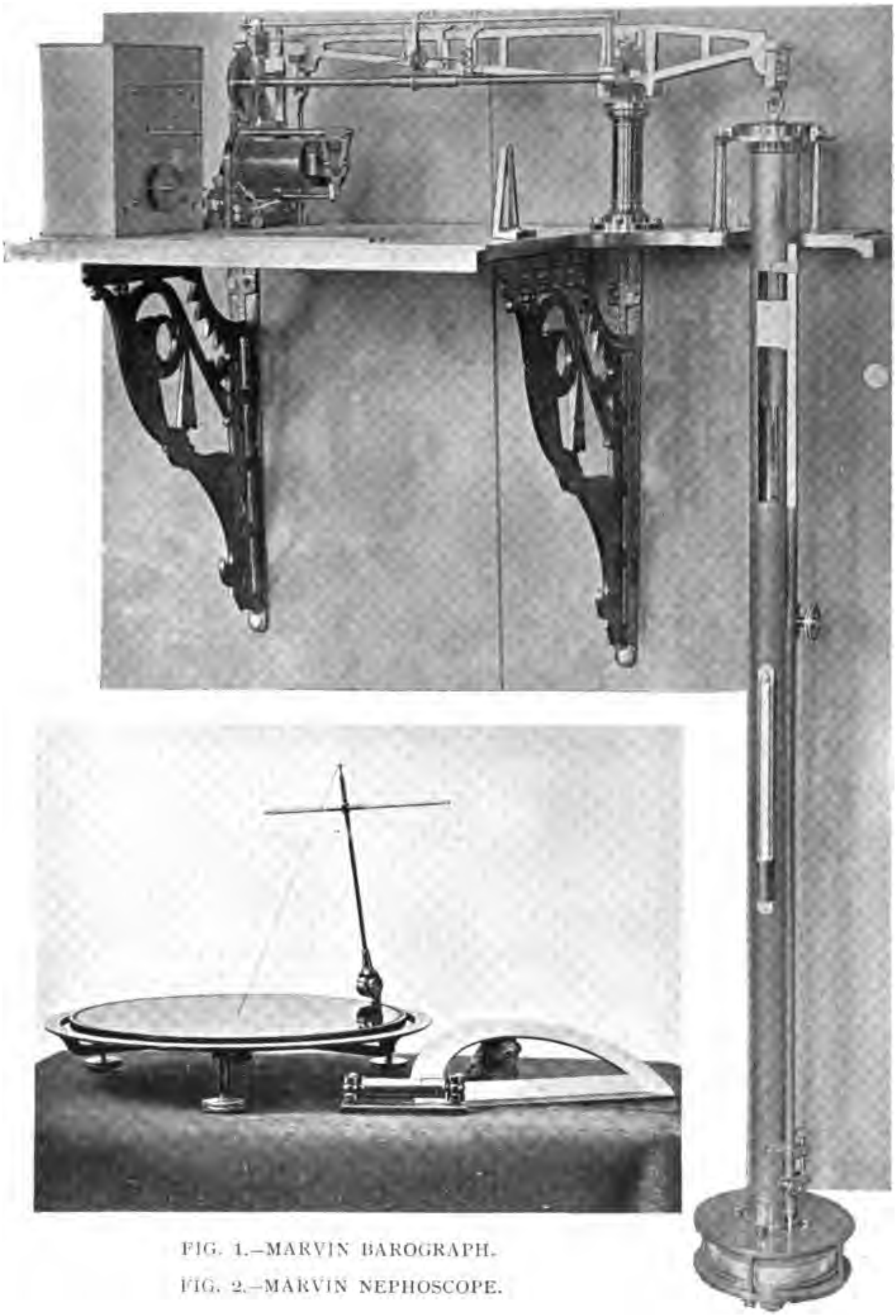


FIG. 1.—MARVIN BAROGRAPH.
FIG. 2.—MARVIN NEPHOSCOPE.

scope and of the methods of computation will be found in my "Treatise on Meteorological Apparatus and Methods," while a special pamphlet on Professor Marvin's nephoscope has been published by the U. S. Weather Bureau.

The use of this nephoscope is very simple. Instead of looking up at the cloud, we look down upon a horizontal mirror and observe the reflected cloud. The latter is just as far below the mirror as the original cloud is above. We turn the mirror around its central pivot until a line graven on the glass exactly covers the apparent path of the cloud as it moves across the sky. The direction in which this line points is the direction of motion of the cloud. If we count the seconds required by the image of the cloud to pass from the center to the edge of the mirror we then have the data for determining the apparent angular velocity, and if by any process we have obtained an idea of the altitude of the cloud, we at once know, approximately, its actual velocity in miles per hour. The altitude may be computed from observations made with two nephoscopes a short distance apart.

The Marvin nephoscope is also exceedingly convenient for determining the apparent angular altitude and azimuth and motion of other objects besides clouds, such as kites, auroras, halos and meteors.

A simple form of nephoscope invented by myself for use on vessels at sea will be found described at page 161 of the U. S. Weather Bureau Bulletin No. 11, and is to be recommended for use by those who, while sailing on the ocean, have sufficient leisure and inclination to add to our scanty knowledge of the motions of the clouds.

One observer sailing on Chesapeake Bay can, with his single nephoscope, determine the altitude, velocity and direction of motion of any cloud provided he knows the velocity and direction of motion of his own boat at two moments of observation. The same results can be accomplished if two nephoscopic observations are made by one person when travelling to and fro on a straight road. In all these cases the apparent movement of the cloud is the result of the composition of the true movements of the cloud and the observer; the process of computation simply resolves the apparent motion into its two elementary motions and the difference in altitude of the observer and the cloud.

Thermographs.

These instruments are designed to keep continuous records of the changes in temperature; they combine some form of self-registering thermometer with some form of record sheet moving uniformly under the influence of clock-work. The Richard thermograph, as used at U. S. Weather Bureau stations, is illustrated in Plate XXXII, Fig. 1. The reader will perceive on the right-hand side, outside of the case, a thin, curved cylinder; this is the thermometer bulb; it is filled with alcohol, and under the relative expansion of the liquid and metal the latter is caused to curve to an extent depending on the temperature. This curvature is magnified considerably before making its record on the sheet of paper that is wrapped around the cylinder on the left-hand side of the diagram. A similar form of thermograph is seen in Plate XXXIII, in connection with the Marvin meteorograph.

Barographs.

These instruments preserve a continuous record of the changes in atmospheric pressure. Of the many types of instruments that are in existence we have illustrated only two, viz., the Richard barograph in Plate XXXII, Fig. 2, and the Marvin barograph in Plate XXXI, Fig. 1. A third form is seen in Plate XXXIII, in connection with the Marvin meteorograph.

The reader will perceive in Plate XXXII, Fig. 2, on the right-hand side, a series of vacuum boxes, one above the other; these boxes are similar to those that were first used in the Vidi aneroid. By combining a number of these together, as in the Richard barograph, the effect of any slight change in atmospheric pressure is made quite appreciable. The top of this series, or "battery," of vacuum boxes is connected with a lever which, acting upon another, eventually produces a magnified movement of the pen on the left-hand side of the diagram. The record is made by this pen upon a sheet of paper or blank form, wrapped around a cylinder that revolves by clock-work. In both the thermograph and barograph of Richard, we have to deal only with differential movements, and in order to deduce true temperatures and pressures from the curves traced by the pens, it is

FIG. 1.—RICHARD'S THERMOGRAPH.

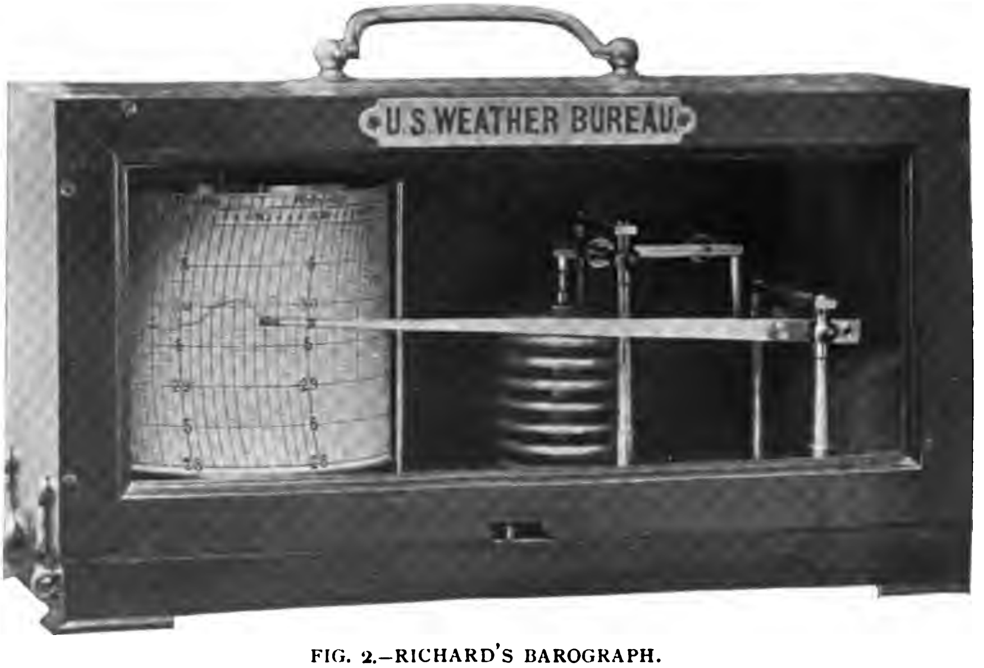


FIG. 2.—RICHARD'S BAROGRAPH.

necessary that comparative readings be made several times daily; these curves are merely used, as it were, to interpolate between these standard readings.

In the Marvin barograph, shown in Plate XXXI, Fig. 1, the idea of a standard barometer, which can be read by the observer at any time, and that of a standard recording apparatus which gives a continuous record of absolute or standard pressures, are both realized. In this diagram the reader will perceive on the right-hand side the tube of a mercurial barometer whose lower end dips into the basin of mercury, while its upper end hangs from one end of a balance beam. As the atmospheric pressure rises, not only does the mercury rise in the interior of the tube, but the pressure downward on the top of the tube increases. The reverse will be true if pressure diminishes. The height of the mercury in the tube may be directly measured by the observer by means of the vertical scale, but it is the changes in the pressure upon the top of the tube that are recorded by the self-registering apparatus. These changes are counterbalanced by a movable weight on the left-hand side of the balance beam. No sooner does the right-hand end of the beam start to rise or fall, on account of changes in pressure, than an electric contact is made and the balance weight is gently pushed to the right or left so as to exactly counterbalance the new pressure. Thus the beam is kept in perfect balance by the motion of the weight, and it is this motion that is registered on a sheet of paper wrapped around a revolving horizontal cylinder. This cylinder can easily be removed in order to change the record sheet, and has been removed in the present illustration so as to allow the rest of the apparatus to be better seen. This barograph by Professor Marvin is the most sensitive and accurate of all that have yet been constructed for the U. S. Weather Bureau, and it preserves a record of the most minute changes in atmospheric pressure, such as those that accompany thunderstorms and gusts of wind.

Self-registering Rain-gauges or Pluviographs.

Quite a variety of devices have been constructed for the continuous record of the rainfall. The rise and fall of a float in the rain-gauge

has always been found to give less reliable records than are needed. Methods of weighing have given good results, but are relatively expensive and cumbersome. The so-called tipping bucket has been used by several national weather bureaus and is widely introduced into the United States. Plate XXVIII illustrates Marvin's tipping bucket rain-gauge. The reader will perceive that the falling rain descending from the rain-gauge on the roof fills one-half of a V-shaped bucket, and when that is filled up to a certain point it tips by its own weight completely to one side and empties its contents while the other half of the bucket is being filled. If no time were lost in the process of tipping the record would be absolutely correct, but as it is, there is usually a loss of about one per cent., due to the fact that one or two drops will fall into the full bucket after it has started to turn and tip.

Triple Register of the Weather Bureau.

This apparatus retains an old name, "triple," although, in fact, it is now modified so as to make a quadruple register, and in one form or other is to be found at most of the U. S. Weather Bureau stations. The quadruple register is illustrated in Plate XXX, Fig. 2. The reader will perceive a narrow cylinder on which the record sheet is wrapped, being about twice as long as it is broad. On this sheet we find recorded (1) the direction of the wind by means of four type, N, S, E, W, which makes an impression every minute, (2) the velocity of the wind, recorded by a pen which makes a little jog in its otherwise straight path for every mile of the standard anemometer rotation, (3) the rainfall recorded by a pen which makes a dot for every hundredth of an inch of the tipping-bucket, and (4) the sunshine which is recorded by the same pen as records the rainfall, the understanding being that there is no sunshine record when the rain is falling.

Kites and Meteorographs.

In order to obtain records from the air within a mile or two of the earth's surface, the kite was first employed by Alexander Wilson

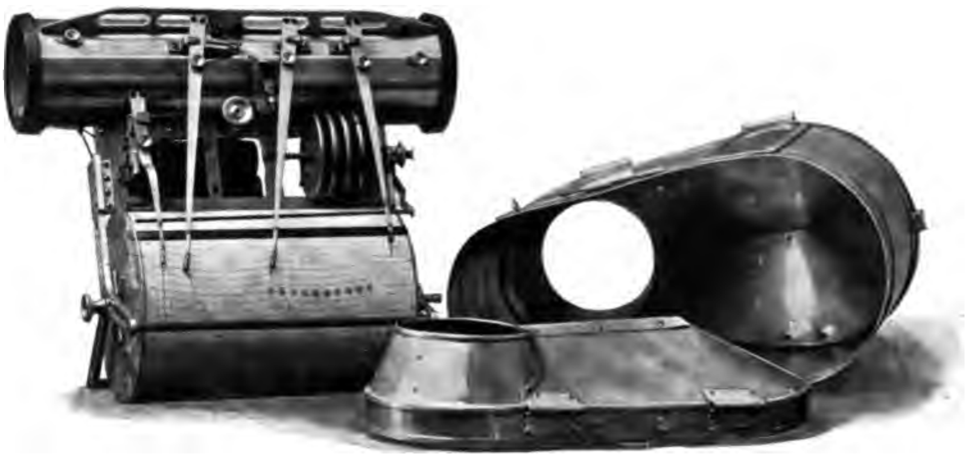


FIG 1.—MARVIN METEOROGRAPH.

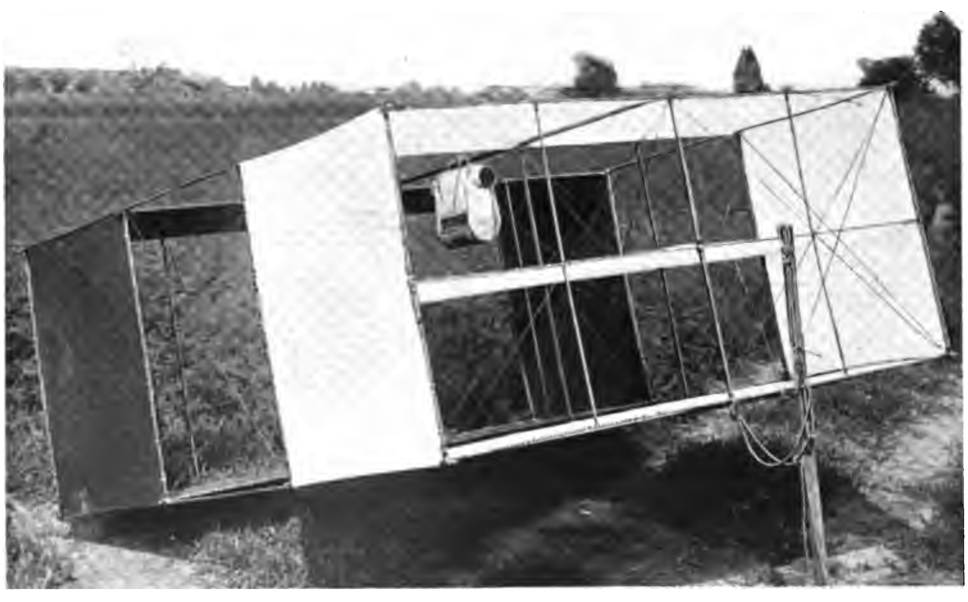


FIG. 2.—KITE AND MARVIN METEOROGRAPH.

of Glasgow in 1749. In 1885, the writer urged the renewed application of the kite, and since the meeting of the International Conference on Aerial Navigation at Chicago in 1893, it has become an important meteorological apparatus. Professor Marvin's construction of the Hargrave cellular kite, or box kite, is fully described in various publications of the U. S. Weather Bureau; the standard size used by him carries about 68 square feet of supporting circuits. The line

FIG. 31.—Marvin's kite-reel.

is of the best steel music wire, whose normal tensile strength is 210 pounds. The Marvin reel, Figure 31, on which the wire is wound, is a modification of the Thomson and Sigsbee deep-sea sounding apparatus; it keeps an automatic record of the pull on the wire, both as to its intensity and direction in altitude and azimuth. The reeling of the wire in and out is done either by hand or by a small gas engine. The meteorological record at the kite is kept on one

sheet of paper by means of the Marvin Meteorograph shown on Plate XXXIII. This keeps a continuous record of the time, by means of an accurate chronograph, of the atmospheric pressure, by means of a Bourdon aneroid, of the temperature of the air by a metallic thermometer, of the relative humidity by a hair hygrometer and of the velocity of the wind by means of a small Robinson anemometer. This complete apparatus is enclosed in an aluminum case to protect it from accident and is lashed securely within the front cell of the kite so that it receives the full force of the wind and, undoubtedly gives a reliable record of the temperature. The entire meteorograph weighs about two pounds. Although kites sometimes break away, yet no injury has occurred to any meteorograph in the course of 1,500 ascensions.

A SKETCH OF THE PROGRESS OF METEOROLOGY IN MARYLAND AND DELAWARE

BY

OLIVER L. FASSIG.

INTRODUCTION.

In the preface of an English volume but little over a century old may be found the following estimate of the value of meteorological observations:

> "Many ingenious gentlemen in different and distant places, at home and abroad, have kept journals of the weather, air and its temperature, and their monthly and yearly quantities of rain; several abstracts of all which I have perused and computed at monthly mediums between the highest and lowest of mercury, or spirits in their tubes, or rain in its receiver; but these being fitter for speculation and amusement than any useful purpose yet known, though if collected, compared and improved, might afford some not contemptible hints, therefore such journals should be deposited in some public museums where the curious might have access to them."

To-day such observations are daily made, and recorded for publication and discussion, at over 25,000 stations upon land and on board thousands of vessels upon the high seas in all parts of the world. There is scarcely a civilized nation that is not maintaining a weather service, large or small. In the United States alone a million dollars in round numbers are annually spent for the maintenance of the national and state weather services.

A century's progress in meteorology is strikingly exhibited in these brief contrasted statements. Maryland and Delaware have shared in this general advance, and it is proposed to call attention to the acts and publications which mark the successive steps of this progress.

Early Accounts of the Weather.

JOHN SMITH, 1606-1608.

As we would naturally expect, our knowledge of the general character of the climate of the neighborhood of Chesapeake Bay begins with the accounts of the first English settlers in the winter of 1606 and 1607. According to John Smith:[1]

"The temperature of this countrie doth agree well with English constitutions, being once seasoned to the country; which appeared by this, that though by many occasions our people fell sicke; yet did they recover by very small meanes, and continued in health, though there were other great causes, not only to have made them sicke, but even to end their dayes, . . ."

Again, ' The sommer is hot as in Spaine; the winter colde as in Fraunce or England. The heat of sommer is in June, July and August, but commonly the coole Breezes asswage the vehemencie of the heat. The chiefe of winter is halfe December, January, February and halfe March. The colde is extreme sharpe, but here the Proverbe is true, that *no extreme long continueth.*"

"The winds here are variable, but the like thunder and lightning to purifie the aire, I have seldome either seene or heard in Europe. From the Southwest come the greatest gusts with thunder and heat. The Northwest winde is commonly coole and bringeth faire weather with it. From the North is the greatest cold, and from the East and Southeast as from the Barmudas, fogs and raines."

"Sometimes there are great droughts, other times much raine." "Within [Capes Henry and Charles] is a country that may have the prerogative over the most pleasant places in Europe, Asia, Africa or America for large and pleasant navigable rivers: heaven and earth never agreed better to frame a place for mans habitation, being of our constitutions, were it fully manured and inhabited by industrious people. Here are mountains, hils, plaines, valleyes, rivers, and brookes, all running most pleasantly into a faire Bay, compassed but for the mouth, with fruitfull and delightsome land."

We learn from Smith that the natives

"Divide the yeare into 5. seasons. Their winter some call *Popanow*, the Spring *Cattapeuk*, the sommer *Cohattayough*, the earing of their corne *Nepinnough*, the harvest and fall of the leafe *Taquitock*. From September untill the midst of November are the chiefe Feasts and sacrifice. Then have they pleanty of fruits as well planted as naturall, as corne greene and ripe, fish, fowle, and wilde beastes exceeding fat."

CAMPANIUS AND THE SWEDISH COLONY, 1644-1715.

The next interesting record of the weather in point of time comes not from the mouth of the James and lower Chesapeake, but from

[1] Capt. John Smith, History of Virginia. The Sixth Voyage, 1606 [o. s.].

the head of Delaware Bay. Here we find what is probably the first attempt in this vicinity to note systematically from day to day the state of the weather for a considerable period.

In one of the early volumes of the Transactions of the American Philosophical Society,[1] Nicholas Collin contributes an article on "Observations made at an early period about the River Delaware," in which there are many interesting notes on the weather about the region between the present sites of Wilmington and Philadelphia, the observers being the settlers of the early Swedish Colony. The author quotes freely from Thomas Campanius Holm's book,[2] "A short account of New Sweden," which is based in great measure on the memoirs of Campanius and the Colonial Documents in the Swedish Archives.

John Campanius, the grandfather of Holm, arrived at Christiana Fort in February, 1643, and did not return to Sweden until 1648. He is said to have kept an account of the weather for every day during the years 1644 and 1645, the character of which is shown in the following extracts:

"February [1644], at first high and cold wind, then snow and sleet, with intervals of warm sunshine, until the 11th; winds N., NE., WNW., S. From the 11th until the 21st cold and clear, sometimes pretty warm, wind generally E. The residue varied with rain, hail, clear and cold; winds S., N., SW., E., NW."

"In the winter 1647 the river was in one night frozen so hard that a deer could run over it; this was, however, an extraordinary case, which the oldest Indians had never known. This winter was the same when, in the month of February, Charles Gustavus, King of Sweden, passed with his army from Holstein over the Belts to the Danish Islands and Copenhagen."

The climate on the whole is represented by Campanius as temperate, healthy and agreeable, having in all the seasons far more of clear, sunny weather than rainy and cloudy.

Hurricanes were called *Mochijric Schackhan*, mightly winds, on which Campanius remarks that "such violent gales came suddenly with a dark-blue cloud and tore up oaks that had a girt of three

[1] Phila., Vol. I (n. s.), 1818, pp. 340-352.
[2] Kort Beskrifning om Nya Sverige. 4°. Stockholm, 1702.

fathoms," here probably having in mind tornadoes rather than hurricanes.

Among the fruits are mentioned grapes of several kinds in great profusion along both sides of the Delaware, one vine near Christiana Creek attaining four feet in circumference, while peach trees are recorded as growing at several localities.

Holm also gives the following extracts from the records kept by the last governor of the Swedish Colony, Rising, and the engineer, Lindstrom, who came to this country in 1654 and remained for a short time:

"The winter begins in December, and ends in January, continuing only seven, eight, or at most, nine weeks, but is, while it lasts, equal in cold to any in Sweden. It sometimes comes on with such violence, that the river would be covered by thick ice in three or four nights, if the billows of the sea were not so forcibly driven into it. When departing, it suddenly breaks up in all the creeks, and the ice drives with the ebb tide to the sea like mountains, and with such a roaring crash, as if a great number of large cannon were discharged. Soon after this the weather becomes quite warm."

Again: "It doth not often rain, but when it does, it is generally with lightning and thunder, tremendous to the sight and hearing. The whole sky seems to be on fire, and nothing can be seen but smoke and flames."

The Reverend Mr. Sandel, Rector of the Swedish Church in Philadelphia, records:

"In 1704, in the latter part of November and December, and in January 1705, we had many, great and lasting snow storms. Few persons could remember such a severe winter."

"In May 1715, a multitude of locusts came out of the ground everywhere, even on the solid roads. They were wholly covered with a shell, over the mouth, body and feet; and it seemed very wonderful, that they could with this penetrate the hard earth. Having come out of the earth, they crept out of the shells, flew away, sat down on the trees, and made a peculiar noise until evening. Being spread over the country in such numbers, the noise was so loud that the cowbells could hardly be heard in the woods. They ripped the bark on the branches of the trees, and put maggots in the openings. Many apprehended that the trees would wither in consequence of this, but no symptom of it was observed next year. Hogs and poultry fed on them. Even the Indians did eat them, especially at their first coming, broiling them a little. This made it probable that they were of the same kind with those that John the Baptist eat. They did not continue long, but died in the month of June."

According to Mr. A. J. Henry,[1] we have an almost continuous record of the character of the winter in the region of the Delaware from 1719 to the present time.

THOMAS GLOVER, 1667.

Returning again to Virginia and the lower Bay, we find the following account of a destructive storm in 1667, probably one of the severe Gulf storms which frequently come up along the Atlantic coast, or, it may be, the continuation of a West Indian hurricane:[2]

"The year 1667, in August, there happened all over Virginia a gust or storm of wind and rain, which continued for three days with such violence, that the like was hardly ever heard of: It began and continued blowing at east with such fierceness that above one half of the crop of their tobacco, which was then standing in their fields, was blown away and torn to pieces; the trees in the woods all over the country were blown up by the roots in innumerable quantity: The waters in the Bay in some places were drove a great way into the woods, and the greatest part of those that housed tobacco, had their tobacco houses blown down, and their tobacco spoiled; so that there was not fully one part of three saved of what would have been made that year."

NATHANIEL SHRIGLEY, 1669.

In "A true relation of Virginia and Maryland," by Nathaniel Shrigley,[3] we find some interesting information about crops:

"The ground is very fruitful, and produceth plentiful crops with great speed, whatever is planted or sown; as for example, one careful laborious man will plant, tend, and get in 50 barrels of Indian Wheat, without the help of Man, Horse or Oxe; each barrel is five English bushels. And if a stone or seed of any fruit be sown, it will bear the third year without grafting; each planter makes great crops of Tobacco; the Western limits of the Land are unknown in Mary-Land; their Religion is free to all that profess to believe in Jesus Christ."

[1] A. J. Henry, Early Individual Observers in the United States. U. S. Weather Bureau, Bull. No 11. 8°. Wash., 1895, p. 293.

[2] Thos. Glover, An Account of Virginia. Phil. Trans., Lond.

[3] 8°. London, 1669.

JOHN CLAYTON, 1688.

By far the most interesting and minute account of weather conditions along the lower Bay that has been found is contained in a letter to the Royal Society of London by John Clayton, Rector of Crofton at Wakefield in Yorkshire. It is dated May 12, 1688, and is entitled " An Account of several Observables in Virginia, more particularly concerning the Air." The full account is contained in the Transactions of the Royal Society of London for that date.

Clayton was a keen observer, and he left England well provided with scientific instruments for accurate observations. Unfortunately, Capt. Win's ship, which followed with all his books and apparatus, including barometers, thermometers and microscopes, went to the bottom of the sea, thus depriving one of the early English settlements along the lower Chesapeake of the distinction of having the first instrumental records of the weather in America.

Even without instruments Mr. Clayton leaves us a most interesting account of weather conditions about Jamestown and the lower Potomac, about the year 1685.

It is probably the earliest detailed account we have of this region; the description is as applicable to-day as it was over two hundred years ago. It is therefore copied with but few omissions from the reprint contained in Volume III of Peter Force's " Collection of Historical Tracts."

The letter opens with an account of his voyage to Virginia:

" By sea I lost all my books, chymical Instruments, glasses and Microscopes, which rendered me incapable of making those Remarks and Observations I had designed, they were all cast away in Captain Win's ship, as they were to follow me; and Virginia being a country where one cannot furnish ones self again with such things, I was discourag'd from making so diligent scrutiny as otherwise I might have done. So that I took very few minutes down in Writing. And therefore since I have only my memory to rely on, which too has the Disadvantage of its own Weakness, and of the Distance of two years since I now left the country, if future Relations shall in some small Points, make out my Mistake, I thought this requisite to justify my Candor. . . .

" The method I design is, first, to give an Account of the Air, and all such observations as refer thereto; then of the Water, the Earth and Soil; the Birds, the Beasts, the Fishes, the Plants, the Insects; and lastly, the present state of the Inhabitants: But at present I shall neither trouble

you nor myself with any more than an account of what refers to the Air alone. . . .

"'Tis commonly asserted by the Seamen, that they can smell the pines at Virginia several Leagues at Sea before they see Land, but I could receive no Satisfaction as to this Point; I could not discern any such thing when at a moderate Distance; I fear much of this may be attributed to Fancy, for one Day there came three or four full scent to tell me they were certain they smelt the Pines: but it afterwards prov'd that we were at that Time two hundred Leagues from the Shoar, so that I was satisfied that was therefore meer Fancy. Indeed we thought, by the general accounts of the Ship, that we had been just on the Coast, but all were deceived by a Current we met with, that at that Time set about South-East, or East South-East, which when once becalmed we tried thus: We hoisted out a Boat, and took one of the Scuttles that covered one of the Hatches of the Ship, tying thereto a great Weight, and a strong long Rope, we let it sink a considerable Depth, and then fastening it to the Boat, it serv'd as an Anchor, that the Boat could not drive; then with the Glass and log Line we found the Current set, as I say, Eastward, at the rate of a mile and a half an Hour. This Current is of mischievous Consequence, it does not always run one way, but as it sets sometimes as we proved Easterly, so does it as they say, set at other Times Westerly, whereby many ships have been lost; for then the Ships being before their Accounts, they fall in with the land before they are aware. Thus one year many ships were lost on Cape Hattarasse, and thereabouts."

Concerning the weather and temperature, Clayton writes:

"The Air and Temperature of the Seasons is much govern'd by Winds in Virginia, both as to heat and cold, driness and moisture, whose variations very notable, I the more lamented the Loss of my Barometers and Thermometers, for considerable observations might be made thereby, there being often great and sudden changes."

"The Nore and Nore-West are very nitrous and piercing; cold and clear, or else stormy. The South-East and South hazy and sultry hot: Their Winter is a fine clear Air, and dry, which renders it very pleasant: Their frosts are short, but sometimes very sharp, that it will freeze the Rivers over Three miles broad; nay, the Secretary of State assured me, it had frozen clever over Potomack River, over against his House, where it is near nine Miles over: I have observed it freeze there the hardest, when from a moist South-East, on a sudden the Wind passing by the Nore, a nitrous sharp Nore-West blows; not with high Gusts, but with a cutting brisk air; and those Vales then that seem to be shelter'd from the Wind, and lie warm, where the air is most stagnant and moist, are frozen the hardest, and seized the soonest; and there the fruits are more subject to blast than where the air has a free Motion. Snow falls sometimes in Pretty Quantity, but rarely continues there above a Day or two. Their Spring is about a month earlier than in England; in April they have frequent Rain, sometimes several short and suddain Gusts. May and June the heat increases, and it is much like our Summer, being mitigated with gentle breezes that rise about nine of the Clock, and decrease and incline as the Sun rises and falls. July and August those Breezes cease, and the Air becomes

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fierce, and that sometimes after violent Thunder and Rain, the Roads would seem to have perfect casts of Brimstone; and 'tis frequent after much Thunder and Lightning for the Air to have a perfect sulphureous Smell. Durst I offer my weak Reasons when I write to so Great Masters thereof, I should here consider the Nature of Thunder, and compare it with some sulphureous Spirits which I have drawn from Coals, that I could no way Condense, yet were inflamable; nay, would burn after they passed through Water and that seemingly fiercer, if they were not overpower'd therewith. I have kept of this Spirit a considerable time in Bladders; and though it appeared as if they were only blown with Air, yet if I let it forth, and fired it with a Match or Candle, it would continue burning till all were spent. It might be worthy Consideration likewise, whether those frequent Thunders proceeded from the Air's being more stagnant, the Motion of the Winds being impeded by the Trees, or whether the Motion of the Winds being obstructed by them below, the Motion might not be more violent aloft; and how far that may promote Inflammability; for Stacks of Hay, or Corn that ferment with Moisture, never burn, unless when brisk Winds blow, that agitate and fan the little fermenting Sparks, and often kindle them into an actual Fire. And observance of the Meteors there might perhaps not be impertinent, as both what are more rare, and what are more frequent, as of Gosimore in great Abundance, and of those small Cobwebs on a Morning, which some have supposed to be Meteors: *Ignes fatui*, though there be many boggy Swamps and Marshes, are seldom, if any are seen there. There be frequent little sorts of whirl-winds, whose Diameter may be sometimes not past two or three yards, sometimes forty, which whisking round in a Circle, pass along the Earth, according to the Motion of the Cloud, from whence they issue: and as they pass along with their gyrous or circular motion, they carry aloft the dry leaves into the Air, which fall again often in places far remote. I have seen them descend in a calm Sunshine Day, as if they had come from the Heavens in great Showers thereof, so that all the Elements seemed filled therewith. And I could perceive them to descend from on high as far as I could possibly discern a Leaf. I remember a roguish Expression of a Seaman, otherwise silly enough, who wondering thereat, cry'd out, *Sure now 'tis manifest there is a World above! And now with them 'tis Fall of the Leaf.* But to proceed, I thought this made it manifest, whence many preternatural Showers have happened. I remember at Sir Richard Atherton's in Lancashire, some few years ago, there fell a great Number of the seeds of Ivy-berries; at first we admir'd what they were, for they were cover'd with a thin Skin that was red, and resembled the Figure of a small Wheat Corn, but afterwards they fully manifested what they were; for many sprouted and took Root. I suppose they were carri'd aloft by some such Whirl-wind, and let fall there. I have purposely gone into the Place where I perceived this Gust, which is notorious enough by the Noise it makes, with ratling the Leaves as it carries them aloft, and have found a fine sharp Breeze of Wind."[1]

FRANKLIN'S OBSERVATIONS CONCERNING NORTH-EAST STORMS, 1747.

The origin of the statement that, in the Atlantic states, storms travel from southwest to northeast is usually and justly attributed to

[1] Trans. Roy. Soc., London, 1688.

Benjamin Franklin, as has been clearly shown by Prof. W. M. Davis.[1] The discovery of this interesting fact is sometimes credited to Lieutenant Evans, upon whose "Map of Virginia," published in 1747, the statement is first given to the public. Franklin's own statements concerning his theory of northeast storms were not published until many years later.

In the complete works of Franklin, recently compiled and edited by John Bigelow and published by Putnam, appears a letter written by Franklin to Jared Eliot concerning this matter; the date of the letter, 1747, together with the remark that he entertained the opinion he expressed for some years, leaves no room for doubt as to the origin of the statement. The letter is as follows:

Philadelphia, July 16th, 1747.

We have had as wet a Summer as has been known here these thirty years, so that it was with difficulty our people got in their harvest. In some parts of the Country a great deal of hay has been lost, and some corn mildewed; but in general the harvest has been very great. The two preceeding Summers (particularly the last) were excessively dry. I think with you it might be of advantage to know what the seasons are in the several parts of the country. One's curiosity in some philosophical points might also be gratified by it.

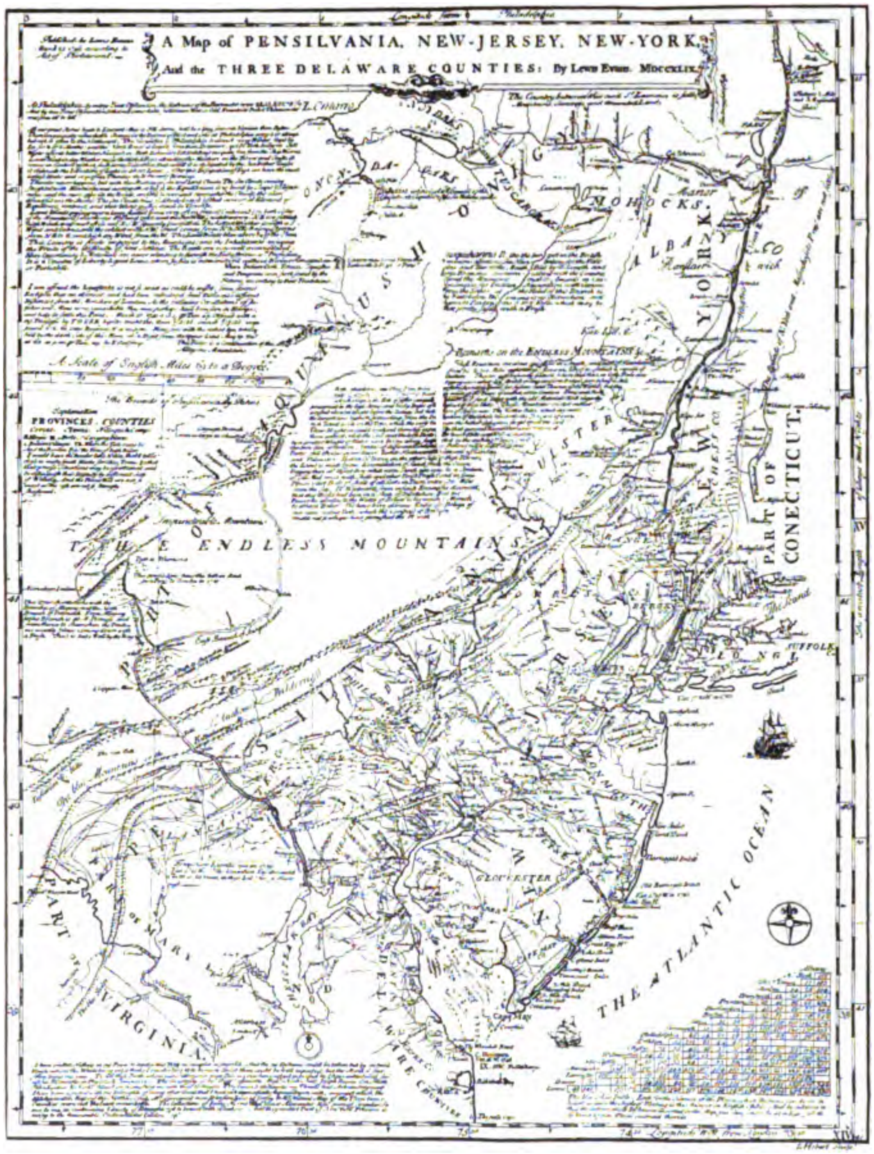
We have frequently, along this North American Coast storms from the Northeast which flow violently sometimes three or four days. Of these I have had a very singular opinion some years, viz., that though the Course of the Wind is from the northeast to southwest yet the course of the storm is from southwest to northeast; that is the air is in violent motion in Virginia before it moves in Connecticut and in Connecticut before it moves at Cape Sable, etc. My reasons for this opinion (if the like have not occurred to you) I will give in my next.[2]

I have not succeeded in finding a copy of the Evans' Map of Virginia, edition of 1747. There is, however, in the Library of the Maryland Historical Society a copy of his "Map of Pensilvania, New Jersey, New York, and the Three Delaware Counties [including portions of Maryland]. . . . Published March 25, 1749, according to act of Parliament."

This map, which is here reproduced, Plate XXXIV, probably con-

[1] Wm. M. Davis, Some American Contributors to Meteorology. Journ. Frankl. Inst., Feb. and Mch., 1889.

[1] Bigelow, Works of Benj. Franklin. Vol. II, 1897, page 76.



LEWIS EVANS' MAP, 1749. (REDUCED.)

[illegible] has been clearly [illegible] the discovery of this interesting [illegible] Evans, upon whose "Map [illegible] 1747, the statement is first given to the p[illegible] ments concerning his theory of northe[illegible] until many years later.

In the complete works of Franklin [illegible] by John Bigelow and published by [illegible] by Franklin to Jared Eliot concern[illegible] letter, 1747, together with the rem[illegible] he expressed for some years, h[illegible] origin of the statement. The le[illegible]

> We have had as wet a Summ[illegible] years, so that it was with dif[illegible] some parts of the Country a[illegible] corn mildewed; but in genera[illegible] preceding Summers (particu[illegible] with you it might be of ad[illegible] several parts of the countr[illegible] might also be gratified by [illegible]
>
> We have frequently, at [illegible] Northeast which flow [illegible] I have had a very sing[illegible] of the Wind is from [illegible] storm is from southw[illegible] Virginia before it [illegible] as Cape Sable etc [illegible]
>
> [illegible]

concerning northeast storms as that found of 1747. As frequently appears in early portions of the states represented on the map sting information of a general character. ies occur referring to the weather:

by many Years Observation, the extremes of the Ba- & 30.78 Ins and by one Years Observation, & that not reme Heat or cold, Fahrenheit's Pocket Thermometer

ms begin to Leeward: thus a N. E. storm shall be a Day than Boston. There are generally remarkable Changes Heat and Cold at Philadelphia every 3 or 4 Days, but not orthward. The Navigation of Philadelphia is almost every Ice for 2 or 3 Months; and tho' North River is longer froze yet N. York, being on salt Water affords better Winter oth Delaware & N. York Bays are quite free from the ship Wind in dry Weather raises the thickest Fogs, attracting on the Rivers and Coasts, it comes in Contact with, in such ties, that, untill it is dissipated by the Sun & other Causes, it he Vibrations of Light in direct lines. After this dissipation have the most intense Heats, and very often Thunder Gusts ning.

never happens, but with the Meeting of Sea and Land Clouds. Clouds coming freighted with Electricity, and meeting others less quilibrium is restored by snaps of Lightning: and the more op- he Winds, and the larger and compacter the Clouds the more dread- the shocks: The Sea Clouds, thus suddenly bereft of that universal nt of Repellency, contract, and their Water gushes down in Torrents. Winds passing over a large shaded (and very often frozen) Continent oth sides of the Mountains) are always dry and cold, and the Sea ds wet and warm. N. E. is a settled high Wind, and most often wet, W squally and unsettled. The hottest Weather is with a S Wind and ms, and the coldest N W. Snow comes from N to N E. Rainy Storms om N E. to E; and high dry Wind from the West. The Land Winds low above ¾ of the year.

This country is finely improved to the Mountains; and the Inhabitants enjoying the Fruits of the Difficulty of first settling. The Roads are very well accommodated. Here opportunity & Materials are never wanting to furnish the Industrious wth Profusion. It is a Country of Liberty & good Laws, where Justice is administered without Rigour or Partiality."

The above bears close resemblance to the published views of Franklin. That Lieutenant Evans does not claim originality for the "sev'l useful Remarks in Physics & Commerce" printed upon his map, will appear from the following quotation also taken from the face of the map:

tains the same statement concerning northeast storms as that found upon the Virginia map of 1747. As frequently appears in early maps, the unexplored portions of the states represented on the map are filled in with interesting information of a general character.

The following entries occur referring to the weather:

"At Philadelphia, by many Years Observation, the extremes of the Barometer were 28.59 & 30.78 Ins and by one Years Observation, & that not remarkable for Extreme Heat or cold, Fahrenheit's Pocket Thermometer was from 14° to 84°.

All our great storms begin to Leeward: thus a N. E. storm shall be a Day sooner in Virginia than Boston. There are generally remarkable Changes in the Degrees of Heat and Cold at Philadelphia every 3 or 4 Days, but not so often to the Northward. The Navigation of Philadelphia is almost every Winter stopt by Ice for 2 or 3 Months; and tho' North River is longer froze than Delaware, yet N. York, being on salt Water affords better Winter Navigation. Both Delaware & N. York Bays are quite free from the ship Worms. Land Wind in dry Weather raises the thickest Fogs, attracting the moisture on the Rivers and Coasts, it comes in Contact with, in such large Quantities, that, untill it is dissipated by the Sun & other Causes, it obstructs the Vibrations of Light in direct lines. After this dissipation of Fogs, we have the most intense Heats, and very often Thunder Gusts toward Evening.

Thunder never happens, but with the Meeting of Sea and Land Clouds. The Sea Clouds coming freighted with Electricity, and meeting others less so, the Equilibrium is restored by snaps of Lightning: and the more opposite the Winds, and the larger and compacter the Clouds the more dreadful are the shocks: The Sea Clouds, thus suddenly bereft of that universal Element of Repellency, contract, and their Water gushes down in Torrents. Land Winds passing over a large shaded (and very often frozen) Continent (on both sides of the Mountains) are always dry and cold, and the Sea Winds wet and warm. N. E. is a settled high Wind, and most often wet, & S W squally and unsettled. The hottest Weather is with a S Wind and Calms, and the coldest N W. Snow comes from N to N E. Rainy Storms from N E. to E; and high dry Wind from the West. The Land Winds blow above ¾ of the year.

This country is finely improved to the Mountains; and the Inhabitants enjoying the Fruits of the Difficulty of first settling. The Roads are very well accommodated. Here opportunity & Materials are never wanting to furnish the Industrious wth Profusion. It is a Country of Liberty & good Laws, where Justice is administered without Rigour or Partiality."

The above bears close resemblance to the published views of Franklin. That Lieutenant Evans does not claim originality for the "sev'l useful Remarks in Physics & Commerce" printed upon his map, will appear from the following quotation also taken from the face of the map:

"I have omitted Nothing in my Power to render this Map as complete as possible. And tho' no Distance could be taken but by actual Mensuration (the Woods being yet so thick) I can declare it to be more exact than could be well expected; but the Merit is far from being my own. To fill these Parts, where our Settlements and Discoveries have not yet extended to, I have introduced sev'l useful Remarks in Physics & Commerce. The Generosity of sev'l Gent.m especially Mess'. Nich'. Scull, Joseph Reeves, Geo. Smith, John Lydins, and Nich'. Stilwil, in furnishing me with their Draughts and Discoveries demands my Thanks and Acknowledgement. I have been assisted with the Draughts of many other Gent. that I had not immediate Acquaintance with, amongst which the Ms. and printed Maps of the Northern Neck, Mr. Lawrence's new Division Line of Jersey & Mr. Noxon's Map of the Three lower Counties were not the least remarkable. The collections of Isaac Norris and James Alexander Esq. were of singular service to me, as containing variety of Draughts not to be met with elsewhere. And the greatest Part of New York Province is owing to the honorable Cadwallader Colden Esq."

This discovery and explanation of the movement of storms was made more than half a century before the fact was rediscovered by Europeans. While the credit of this most important discovery belongs to Pennsylvania rather than to Maryland or Delaware, still the field of Franklin's investigations embraced Georgia, Virginia, Maryland and all of the Atlantic States. As Franklin's own account of his reasoning is not very familiar, it may not be out of place to give it greater publicity here:

(Extract from a letter to Jared Eliot.[1])

Philadelphia, 13 February, 1750.

You desire to know my thoughts about the northwest storms beginning to leeward. Some years since there was an eclipse of the moon at nine o'clock in the evening, which I intended to observe, but before night a storm blew up at northeast and continued violent all night and all next day; the sky thick-clouded, dark and rainy so that neither moon nor stars could be seen. The storm did a great deal of damage all along the coast, for we had accounts of it in the newspapers from Boston, Newport, New York, Maryland and Virginia; but what surprised me was to find in the Boston newspapers an account of an observation of that eclipse made there; for I thought as the storm came from the northeast it must have begun sooner at Boston than with us, and consequently prevented such observation. I wrote to my brother about it and he informed me that the eclipse was over there an hour before the storm began. Since which I have made inquiries from time to time of travellers and of my correspondents, northeastward and southwestward, and observed the accounts in the newspapers from New England, New York, Maryland, Virginia and South Carolina; and I

[1] Bigelow, Works of Benj. Franklin, Vol. II, 1887, pages 161-164.

find it to be a constant fact, that northeast storms begin to leeward and are often more violent there than farther to windward. Thus the last October storm which with you was on the eighth, began on the 7th in Virginia and North Carolina and was most violent there. As to the reason of this I can only give you my conjectures. Suppose a great tract of country land and sea to wit, Florida and the Bay of Mexico to have clear weather for several days, and to be heated by the sun and its air thereby exceedingly rarefied. Suppose the country northeastward, as Pennsylvania, New England, Nova Scotia and Newfoundland to be at the same time covered with clouds, and its air chilled and condensed. The rarefied air being lighter must rise, and the denser air next to it will press into its place; that will be followed by the next denser air that by the next, and so on. Thus when I have a fire in my chimney there is a current of air constantly flowing from the door to the chimney; but the beginning of the motion was at the chimney where the air being rarefied by the fire rising its place was supplied by the cooler air that was next to it and the place of that by the next and so on to the door. So the water in a long sluice or mill-race being stopped by a gate is at rest like the air in a calm. but as soon as you open the gate at one end to let it out the water next to the gate begins first to move, that which is next to it follows; and so though the water proceeds forward to the gate the motion which began there runs backwards if one may so speak to the upper end of the race where the water is last in motion. We have on this continent a long ridge of mountains running from northeast to southwest and the coast runs the same course. These may perhaps contribute towards the direction of the winds, or at least influence them in some degree. If these conjectures do not satisfy you, I wish to have yours on the subject.

It has been shown that the eclipse referred to above happened October 21st, 1743.

MASON AND DIXON, 1763-1767.

The daily journal of Chas. Mason and Jere Dixon, while running the boundary line between Pennsylvania and Maryland, is of interest to us in this connection. No attempt was made by these engineers to keep a continuous record of the weather, but they recorded from day to day, during the progress of the survey, between 1763 and 1767, the fact that star observations were made, or that observations were interrupted owing to rain, snow or cloudy weather or to other causes. Thus we learn, for example, from the record of March and April, 1765:

" 12-20, observations attempted but interrupted by clouds and rain; 21, 22, 23, snow; 24, at 9 a. m. snow was near 3 feet deep; 25, 26, 27,

snow so deep we could not proceed; 28, observations dubious; 29, 30, 31, cloudy.

April 1, 2, 3, cloudy; 4-16, continued the line, 16-21, star observations; 29, 30, continued the line."

THE HAGERSTOWN ALMANAC, 1797-1899.

Next to the Bible there is probably no form of publication more widely distributed and cherished by the people in all countries than the almanac. Recently Dr. Hellmann[1] of Berlin, reprinted in *fac-*

FIG. 32.— John Gruber.

simile two of the earliest forms printed in the German language, together with a most interesting critical analysis, and a bibliography of the different editions and translations.

In 34 years, from 1505 to 1540, the *Wetterbüchlein* passed through 17 editions; from 1530 to 1590 the *Bauern Praktik* passed through 29 editions; and there were in all 59 editions. They are based largely upon natural weather signs, supplemented by astronomical supersti-

[1] L. Reynman. Wetterbüchlein. 1510. 16 pp. Reprinted. 4°. Berlin, 1893, 55 pp. Die Bauern Praktik. 1508. 12 pp. Reprinted. 4°. Berlin, 1896. 83 pp.

tions. These almanacs have been translated and reprinted, with many alterations and additions, in many languages. Their English representatives appear under various titles, such as "The husbandman's practice, or prognostication forever," "The Shepperd's perpetual prognostication of the Weather," "The Shepperd's Kalender; or, the Citizen's and Countryman's daily Companion." Dr.

FIG. 33.—Cover of the first edition of the Hagerstown Almanac.

Hellmann places the origin of these books far back in remote antiquity; in all probability they are of Indo-Germanic origin. In the almanac of to-day, weather prognostics occupy but a relatively small portion of the total space. The calender, the rising and setting of the sun and moon, the aspects of the planets, the moon's phases, eclipses, etc., form the major part, filled in with more or less useful advice and entertaining reading matter. In a short paragraph the

general character of the weather for each day of the month is vaguely conjectured.

Probably the most interesting American representative of this class of literature is the Hagerstown Almanac. It has had a long and honorable career. The first editor and publisher was John Gruber. He was of German origin, the son of a physician. The first ancestor who emigrated to America was the grandfather, John Adam Gruber,


Der neue Nord-Americanische
Stadt und Land
Calender,
Auf das Jahr Christi
1797.
Welches ein gemein Jahr ist von 365 Tagen.
Darinnen, nebst richtiger Festrechnung, die Sonn- und Monds-Finsternisse, des Monds Gestalt und Viertel, Monds-Aufgang, Monds-Zeichen, Aspecten der Planeten und Witterung, Sonnen Auf- und Untergang, des Siebengestirns Aufgang, Südplatz und Untergang, der Venus Auf- und Untergang, Courten, Fairs, eine Uhr-Tafel und andere zu einem Calender gehörige Sachen zu finden.
Nebst einer kurzen Beschreibung von Kentucky, u. s. w.
Nach dem Märyländischen Horizont und Nordhöhe berechnet; besonders für die Westlichen Gegenden in Pennsylvanien, Maryland und Virginien: Jedoch in denen angrenzenden Staaten ohne merklichen Unterschied zu gebrauchen.
Zum Erstenmal herausgegeben.
Hägerstaun, gedruckt und zu haben bey Johann Gruber, nahe beym Courthaus; Wie auch bey unterschiedlichen Storehaltern und andern zu finden.

FIG. 34.—Title-page of the first edition of the Hagerstown Almanac.

who settled in Germantown, Pa., in 1726. John Gruber was born in Strasburgh, Lancaster County, Pa., in 1768. In 1793 he went to Reading, Pa., where he published a paper: *Neue Unpartheyische Readinger Zeitung und Anzeigs-Nachrichten.* Two years later he settled in Hagerstown, Maryland, where he remained until his death in December, 1857. Mr. Gruber published his first almanac in 1797, in the German language. It has appeared regularly each year since with but little change in form and style of printing. Since

1822 it has also appeared in the English language. The cover and title-page of both the English and German editions are to-day identical with those of the first editions, with the exception of change in dates. The quaint wood-cuts, symbolical of the months of the year, have remained unchanged since first designed by the founder. The weather conjectures of the Hagerstown Almanac are apparently based upon a supposed influence of the moon. That the moon has a direct influence in bringing about weather changes is so firmly implanted in the popular mind, and to a large extent also in the scientific mind, that it will probably never be completely eradicated. *How* this influence is brought about has never been stated to the satisfaction of the man of science.

The table for foretelling the weather, as it appears in the Hagerstown Almanac, and the one which is commonly used in similar publications, is here reproduced:

WEATHER PROGNOSTICATOR.

A Table for Foretelling the Weather through all the Lunations of each Year.

This table and the accompanying remarks are the result of many years' actual observation; the whole being constructed on a due consideration of the attraction of the sun and moon, in their several positions respecting the earth; and will, by simple inspection, show the observer what kind of weather will most probably follow the entrance of the moon into any of her quarters, and that so near the truth, as to be seldom or never found to fail.

If the New Moon, First Quarter, Full Moon, or Last Quarter, happen—	IN SUMMER.	IN WINTER.
Between midnight and 2 in the morning	Fair	Hard frost, unless the wind be S. or S. W.
Between 2 and 4 morning	Cold with frequent showers	Snow and stormy.
Between 4 and 6 morning	Rain	Rain.
Between 6 and 8 morning	Wind and rain	Stormy.
Between 8 and 10 morning	Changeable	Cold rain, if wind be W.; snow, if E.
Between 10 and 12 morning	Frequent showers	Cold and high wind.
At 12 o'clock at noon and 2 in the afternoon	Very rainy	Snow or rain.
Between 2 and 4 in afternoon	Changeable	Fair and mild.
Between 4 and 6 in afternoon	Fair	Fair.
Betw'n 6 and 8 in aftern'n	Fair, if wind N. W. Rainy, if S. or S. W.	Fair and frosty, if wind N. or N. E. Rain or snow, if S. or S. W.
Between 8 and 10 in aftern'n	Ditto	Ditto.
Between 10 and midnight	Fair	Fair and frosty.

Observations.—1. The nearer the time of the Moon's change, First Quarter, Full and Last Quarter are to Midnight, the fairer will the weather be during the seven days following.

2. The space for this calculation occupies from ten at night till two next morning.

3. The nearer to midday or noon these phases of the moon happen, the more foul or wet weather may be expected during the next seven days.

4. The space for this calculation occupies from ten in the forenoon to two in the afternoon. These observations refer principally to the summer, though they affect spring and autumn nearly in the same ratio.

5. The Moon's change, First Quarter, Full Moon and Last Quarter, happening during six of the afternoon hours, that is from four to ten, may be followed by fair weather; but this is mostly dependent on the wind, as it is noted in the table.

6. Though the weather, from a variety of irregular causes, is more uncertain in the latter part of autumn, the whole of winter, and the beginning of spring, yet in the main, the above observations will apply to those periods also.

Early Instrumental Observations.

Dr. Richard Brooke, 1753-1757.

To the best of our knowledge, the first instrumental observations of the weather, or rather of air temperature, made within the present limits of the states of Maryland and Delaware, are those of Dr. Richard Brooke. The observations for the first year, September 1, 1753, to August 31, 1754, are published *in extenso* in the Philosophical Transactions of the Royal Society of London for 1759. The record comprises a morning and an afternoon observation of the temperature of the air, the direction of the wind, and the state of the weather.

From September, 1754, to December, 1757, the published record comprises only the highest and lowest reading of the temperature in each month and the general character of the weather during the month, with occasional remarks about unusual weather conditions or prevalent diseases. Strange to say, there is nothing in the published records to reveal the place of observations, further than that they were made in Maryland. Dr. Richard Brooke was the son of Thomas Brooke and Lucy, daughter of Col. Walter Smith. He was born near Nottingham in Prince George's county on June 2nd, 1716, and died on July 12th, 1783. He lived on the family estate, "Brookfield." Dr. Brooke took an active part in politics, and was

a man of some note in his day. The weather observations were doubtless made at Brookfield.

Below there are brought together in the form of a table, the highest and lowest temperatures recorded by Dr. Brooke during each month from September, 1753, to December, 1757.

Month.	Year.									
	1753.		1754.		1755.		1756.		1857.	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
January	....	....	64	15	69	23	73	15	65	10
February	....	....	61	10	64	14	70	27	67	8
March	....	....	71	27	79	24	....	....	65	30
April	....	....	73	42	83	40	83	29	67	35
May	....	....	85	46	87	47	81	48	88	48
June	....	....	87	57	90	70	86	44	90	72
July	...	....	87	61	93	60	93	69	90	64
August	....	....	88	62	90	61	93	68	90	67
September	87	58	80	? 73	93	45	92	60	88	47
October	74	36	80	34	75	36	90	29	67	43
November	63	36	67	23	65	29	73	27	65	33
December	69	11	60	23	71	15	63	13	68	28

An inspection of the figures shows no remarkable records, as they are neither higher nor lower than are shown by records of to-day in the same neighborhood and for the same time of year.

The morning hour of observation was probably about 7 A. M., and the afternoon hour about 2 P. M., approximately the coldest and warmest hours of the day. The exact time is, however, not stated, nor is there any description of the thermometer used.

A few extracts from the record of Dr. Brooke may be of interest:—

"On the 16th of April, 1755, it snowed as hard as ever I knew. Cleared up at 2 o'clock p. m. All dissolved before night. Not one shower of rain this month. Wind easterly 'till the 14th, afterward mostly westward."

A drought prevailed during the summer of 1755. May is described as "extremely dry; seldom any clouds; no rain. Every vegetable almost burnt up; strawberry leaves, green plantain, and others, so crisp as to crumble. In this month many black cattle died for want of food." June of this year was "seasonable"; July,

August, and September, "very dry," October "seasonable toward the close of the month." . . . "This was the dryest summer and autumn ever remembered."

"On Tuesday the 18th [of November, 1755,] I felt three shocks of an earthquake about 8 minutes before 4 in the morning. The first was severest; it shook the house very much, and waked me. The second was less, and the third least of all. They succeeded each other at about one minute's distance and were felt all over the continent."

The passage of a cold wave in December, 1755, is described as follows:

"On the 16th there was a brisk southerly wind; the mercury about noon at 71°; at 4 p. m. at 69°; at 5 o'clock the wind came about to northwest, blew excessively hard, and did great damage in the country. A prodigious quantity of rain fell; it cleared up at 6 o'clock; but the wind continued blowing hard all night. At 8 o'clock the mercury was at 43°, at seven the next morning at 26°, at nine at 24½°, and the morning following, viz., the 18th, the mercury was at 15°."

Another cold wave is recorded in January, 1757. "Many sudden alternations, as to heat and cold, have been in this month; but the most remarkable I have ever observed, was the last day of this month, when the mercury was up at 65°, and the next day, February 1, when it was down at 28°, about the same hour in the day."

Dr. Brooke seems to have forgotten his own record of the cold wave of December 17th, 1755, during which the temperature fell about 45° in twenty-four hours.

On the recurrence of a severe storm on the 22d of June, 1756, Dr. Brooke records:

"On the 22d in the morning a black cloud came from the northward, soon overspread the hemisphere, and threatened much wind and rain; but soon blew over without much wind or rain. The sun shone clear, and the weather calm, till toward noon, when clouds collected toward the north and northwest. About 3 p. m. there was the most threatening appearance I ever beheld, the clouds in some places of a deep green, in others of a sooty black. At 45 minutes

past 3 it began to rain and blow, attended with remarkable severe thunder; but as the thunder stopped the clock, I cannot say how long it lasted; but suppose near half an hour; in which time the most rain fell I ever saw. The wind did incredible damage in several parts of the country. In St. Mary's County, it is said, 200 houses were blown down, and many people killed. In every county in Maryland much damage was done by this gust, which was the most general ever remembered. It was all over New York, the Jerseys, Pennsylvania, Maryland, Virginia, and did much damage everywhere. How much farther it extended either northward or southward, I have not heard."

The summer of 1756 was very dry. In September Dr. Brooke observes: "This is the hottest and dryest summer ever known in Maryland. There are great crops of corn and tobacco made; but through the extreme dryness of the weather, the later crops of neither will come to perfection. Many springs are dried up that were ever current before."

"On the 10th day of this month [November, 1757,] there was as severe a gust of thunder and lightning as is common in July or August. Several horses, cattle, etc., were killed in different parts. There were the most luminous coruscations I ever saw; the whole hemisphere as it were in a blaze."

CAPTAIN LEWIS BRANTZ, 1817-1837.

No record has been found of systematic observations made in Maryland or Delaware between the years 1757 and 1817. From 1817 to 1824, however, there is an excellent series made by Capt. Lewis Brantz of Baltimore. Capt. Brantz observed daily at 8 A. M., 2 P. M., and 10 P. M., noting the temperature, winds, clouds and rainfall. The results were published in pamphlet form, and a complete file, bound into a single volume, is preserved in the Library of the Maryland Historical Society. Capt. Brantz doubtless continued his observations for several years longer, as there are several references to fragmentary records made in 1829, 1836, 1837 and 1838, and to the fact that the barometer and hygrometer were added to his equipment of instruments in 1836. He was elected a member of

the Maryland Academy of Science and Literature in 1836, and was also a member of the Meteorological Committee of that body.

FREDERICK, 1821-1899.

I am indebted to Mr. McClintock Young, at present the voluntary observer at Frederick, for information concerning a long record of the weather kept at Frederick. Mr. Young states that there is in the possession of Mr. Allen G. Quynn of that city a continuous record of temperature, character of the day, heavy or remarkable rains, snows and storms from February, 1836, to the present time. The early temperature observations were made for a time at sunrise only, a portion at sunrise and sunset, a portion at sunrise, noon and sunset. Mr. Quynn states that the record originally began about 1821, but that the earlier portion, from about 1821 to 1836, has been lost.

DR. SAMUEL KER, 1823-1847.

Dr. Samuel Ker kept a continuous record of the temperature of the air and of rainfall at Princess Anne from about 1823 to about 1847. Some of these observations were published, at the time they were made, in a local paper, the Somerset Herald. A portion of this record is in the possession of Mr. A. E. Acworth of Mardela Springs, a voluntary observer of the Maryland Service. Dr. Ker studied medicine in Philadelphia as a pupil of Dr. Rush. He began the practice of his profession near Princess Anne, but later removed to Princess Anne, where he resided until his death in 1851.

THE DISTRICT OF COLUMBIA, 1820.

In Washington City we find several short series of observations belonging to the early part of the present century. Among the first, we have a record extending over two years, 1820 and 1821, by the distinguished observers John Quincy Adams and General Josiah Meigs. From 1822 to 1824 observations were made daily by Jules de Wallenstein, of the Russian Legation. In Elliot's "Historical Sketches of the 10 miles Square," there is a record of the maximum and minimum temperatures made in Mt. Pleasant for the two years 1828 and 1829. Judge W. C. Cranch kept a record from

1823 to 1839. Charles H. Trunnell, still a resident of Georgetown, or West Washington, has kept a continuous record from 1848 to the present time, noting only the general character of the day, occurrence of rain, or snow, thunderstorms, and unusual weather conditions.

In the foregoing discussion reference has been made only to such observations as were made by individuals not connected with any institution, while the following remarks relate to observations made under the auspices of scientific institutions or by direction of the national and state governments.

Organized Climatological Systems Represented in Maryland and Delaware.

THE ARMY MEDICAL DEPARTMENT, 1814.

In 1780 the Mannheim Meteorological Society in Germany was organized, and a system of stations was established, equipped with instruments previously compared and tested with standards. This is generally recognized as the first effort to secure meteorological observations at a number of stations under conditions making the observations comparable.

In this country the systematic collection of climatological statistics received early attention in the U. S. Army Medical Department. As Major Smart observes,[1] "Meteorological science in the United States was conceived and brought forth by the Army Medical Department." The earliest meteorological journal on file in the office of the Surgeon-General in Washington is dated Cambridge, Mass., July, 1816. On its first page is written:

"Among the rules for the Medical Staff of the United States is that which makes it the duty of each hospital surgeon and director of a department 'To keep a diary of the weather, together with an account of the medical topography of the country in which he serves, wherefore the following sketch of Boston and its vicinity, and particularly of Charlestown, is offered to the Commander in Chief, Major General Brown, by Benj. Waterhouse, M. D., hospital surgeon and director of Dept. No. 2, Northern Division, as a first step in fulfilling this desideratum.'"

[1] Major Charles Smart. The Army Medical Department and Meteorology in the United States. U. S. Weather Bureau, Bull. No. 11. 8°. Washington, 1895. pp. 207-216.

The first order which Major Smart finds in the "Military Laws, Rules and Regulations of the United States" relating to the duty of hospital surgeons to keep a diary of the weather is one dated May 2, 1814. At that time the Surgeon-General of the Army was Dr. James Tilton of Delaware. In the opinion of Major Smart, "There seems to be little doubt that the credit of instituting meteorological records at our permanent posts and hospitals should belong actually as well as officially to Dr. Tilton."

As a result of this system we have three long and valuable records of the weather in Maryland and one in Delaware. The record at Fort Severn, now the site of the U. S. Naval Academy, begins in 1822, and extends with considerable interruption, however, until 1876. At Fort McHenry observations were begun in 1831, and continued, with the exception of about three years, until 1892. At Fort Washington, Prince George's county, we have a more or less broken record beginning in 1824 and ending in 1872. The record at Fort Delaware, near Delaware City, extends from 1825 to 1859, and again from 1862 to 1870. The policy of the Surgeon-General's Office has been to discontinue observations after the establishment of a U. S. Weather Bureau station in the vicinity of the military post.

Further information as to the character of the observations made at military posts, and as to the hours of observation, is given in connection with the list of stations which forms one of the appendices to this account.

About 1840 Mr. James P. Espy, one of the greatest of American meteorologists, became attached to the Surgeon-General's Office in Washington City. He very soon set about enlisting the services of colleges and schools, as well as individuals, in the work of collecting statistics of the weather, especially such facts as would aid him in the development of his cherished theory of storms. The Maryland observations used in Espy's discussion of storms during this period are those of Mr. Finch at Elkton, Prof. Giraud and Mr. F. G. Hoover at Emmitsburg, Robert Banning at Isthmus, Talbot county, and Mr. T. C. Atkinson at Mt. Savage, Allegany county, in addition to those made at the military posts.

THE SYSTEM OF THE U. S. LAND OFFICE, 1817.

As early as 1817 General Josiah Meigs, Commissioner of the General Land Office in Washington City, "suggested in a note to an influential member of Congress, whether a resolution might not pass authorizing the President of the United States to cause meteorological registers to be kept at each of the Land Offices of the United States under the direction of the Commissioner of the General Land Office, and that the meteorological observations should be returned monthly to the General Land Office with their official returns."

General Meigs failed to secure authority for this, but did not give up his efforts to secure the observations. In April, 1817, he addressed a circular to the registers throughout the country requesting them to take regularly certain meteorological observations, forwarding blanks to them for the purpose. The plan had thus to be placed upon a voluntary basis. Observations were continued for several years. These land offices were established entirely in the unsettled central and western states, so that Maryland is not represented in this system. Two or three of the stations in Washington City probably reported to General Meigs.

THE FRANKLIN INSTITUTE, 1834-1844.

In 1834 the Franklin Institute of Philadelphia, at the instigation of James P. Espy and others, issued a circular requesting observations of the temperature of the air, temperature of the wet-bulb thermometer, the dew-point, wind direction and strength, clouds, rainfall and pressure. The chief purpose of this request was the study of storms and not especially for continuous observations. In answer to this request Mr. Espy received reports from several points in Maryland and Delaware.

The records show that during 1835 and 1836 reports were received from Dr. G. S. Sproston, U. S. N., Baltimore; during 1838 and 1839 from President H. Humphrey, of St. John's College, Annapolis; Professor Elder, of Mt. St. Mary's College, Emmitsburg; and from unknown observers at Snow Hill, Worcester county, and Elkton, Cecil county. Reports were also received during 1834 and 1835 from Dr. Henry Gibbons, Wilmington, Delaware.

THE SMITHSONIAN INSTITUTION, 1847-1874.

The year 1847 marks a most important epoch in the history of meteorology in this country. It was the year in which Prof. Joseph Henry was appointed Secretary of the Smithsonian Institution. The time was propitious for rapid advance in meteorology; at the same time a man fully equal to the emergency appeared upon the scene. Prof. Henry had already done good work in connection with the establishment of the excellent meteorological system in New York state under the auspices of the Board of Regents of the University; in addition, he was personally much interested in meteorological problems. In the "Programme of Organization" submitted in December, 1847, to the Regents of the Smithsonian Institution, Prof. Henry urges immediate attention to a "system of extended meteorological observations for solving the problems of American storms."

Prof. Henry proposed, in his scheme, to cover the entire North American continent with a network of stations; to secure the coöperation of an intelligent body of voluntary observers and supply them with standard instruments and the necessary blank forms upon which to return to the Smithsonian Institution a monthly record of all observations.

The Board of Regents at once assented to Prof. Henry's proposition, and, on December 15, 1847, appropriated "one thousand dollars for instruments and other expenses connected with meteorological observations." This was the beginning of the meteorological work of the Smithsonian Institution.

At this time there were several independent systems of observation in existence in the United States, viz., that of the Army Medical Department; the system inaugurated by the Regents of the University of New York in connection with the academies and high schools of the state in 1825; and that established by the Legislature of Pennsylvania in 1837, providing for one station in each county of the state.

The efforts of the Secretary were directed to [1]—

"Supplementing and harmonizing all the other systems, preparing and distributing blank forms and instructions, calculating and publishing

[1] Ann. Rep. Smith. Inst. 1866, p. 53.

extensive tables for the reduction of observations, introducing standard instruments, and collecting all public documents, printed matter, and MS. records bearing on the meteorology of the American Continent, submitting these materials to scientific discussion, and publishing the results."

Again quoting the language of the Secretary:[1]

"The primary object of the Smithsonian Institution is the advancement of the science of meteorology and the elucidation of the laws of atmospheric phenomena; that of the Patent Office, to collect facts and deduce therefrom laws which have immediate reference to agriculture; while the system of the Medical Department is intended to be primarily subservient to the health of the troops and the advancement of medical science. These three Institutions are now in harmonious co-operation, and it is believed that it is no exaggeration to say that under their auspices more is now being done to advance meteorology than has ever before been attempted under any government."

The organization and aims of the Smithsonian Institution are here referred to at some length, as practically all Maryland and Delaware weather records between 1849 and 1874 were made under its auspices. In Maryland alone there were at one time and another during this period 35 stations; in Delaware 3, and in the District of Columbia 7.

It was a rule with Prof. Henry to originate and to develop useful lines of scientific research which were not otherwise properly provided for, and to foster them until taken up by the national government. As early as 1865 he suggests that "the present would appear to be a favorable time to urge upon Congress the importance of making provision for reorganizing all the meteorological observations of the United States under one combined plan, in which the records should be sent to a central depot for discussion and final publication."[2]

In 1870 the National Weather Service was established by act of Congress. In 1874 the formal transfer of all observers of the Smithsonian Institution to the U. S. Weather Bureau took place, and thereafter all reports were sent direct to the latter. In 1891 all the MS. meteorological records in the possession of the Smithsonian Institution were placed in the keeping of the U. S. Weather Bureau,

[1] In the preface to "Results of meteorol. observ. in 1854-59 under the direction of the Smith. Inst. and the U. S. Patent Office." 4°. Wash., 1861. Vol. I.

[2] Ann. Rep. Smith. Inst. 1865, page 57.

subject, however, to recall. A list of all stations in Maryland, Delaware and the District of Columbia reporting to the Smithsonian Institution, together with a brief description of each, will be found in another part of this sketch.

No one has done more for meteorology in America than Prof. Henry. The wisdom of his planning and his efficiency as an executive officer are not only shown in organizing and successfully maintaining an excellent network of stations at small expense for over 25 years; they are equally conspicuous in providing for intelligent reduction and discussion, by the best experts, of the vast amount of material collected; the publication and wide distribution of the results thus obtained, and by the wise selection and publication in the Annual Reports of the Smithsonian Institution, and in special memoirs, of the best results of the world's scientific research wherever found.

It is worthy of mention in this connection that the last feeble utterance of Prof. Henry, as he lay on his death-bed, was an inquiry "which way the wind came."

THE U. S. PATENT OFFICE AND THE SMITHSONIAN INSTITUTION, 1854-1860.

From 1854 to 1860 an annual appropriation was made by Congress for the collection of agricultural statistics, investigations for promoting agriculture and rural economy. A portion of this appropriation was devoted by the Commissioner of Patents to assisting the Smithsonian Institution in collecting and reducing meteorological observations. The result is shown in two large quarto volumes in which the meteorological and phenological observations collected by the Institution between 1854 and 1859 are brought together and printed *in extenso*. These volumes contain much valuable material received from Maryland during those years.

THE NATIONAL WEATHER BUREAU, 1870-1899.

The act of Congress of February, 1870, providing for the establishment of a National Weather Bureau, was the logical and almost inevitable next step in the development of meteorology in this country. The work of the Army Medical Department, of the Land Office, of

the Hydrographic Office of the Navy, and especially of the Smithsonian Institution, paved the way for bringing all the meteorological work of the country under one central head, under the auspices of the general government. The usefulness of such a service had been fully demonstrated in the interests of agriculture, of commerce, and of the community at large, and it remained only to present the matter before Congress in such a way as to convince the majority of the lawmakers of the wisdom of such a step. How this was brought about is well told by Prof. Abbe,[1] who was himself largely instrumental in bringing the national bureau into existence, then known as the Signal Service, U. S. Army. Congress provided for "Taking meteorological observations at the military stations in the interior of the continent, and at other points in the states and territories of the United States, and for giving notice on the Northern Lakes and the seacoast by magnetic telegraph and marine signals of the approach and force of storms."

The U. S. Weather Bureau was organized on a military basis, with Brigadier-General Albert J. Myer, the Chief Signal Officer of the Army, in charge. It remained a Bureau of the War Department until July 1, 1891, when it became a part of the civil administration under the Secretary of Agriculture. Among the first stations to be established was that at Baltimore, which, from the beginning, has been maintained as one of the best equipped stations in the service. Air pressure and temperature, wind direction and velocity, sunshine and rainfall are recorded continuously by means of self-recording instruments; other elements of the weather are recorded twice a day from eye observations. Maryland has had one other station of the national system, one of the second order, that at Ocean City from 1882 to 1887. Two second-order stations were maintained in Delaware for short periods; one at Delaware Breakwater, from 1880 to 1885, the other at Cape Henlopen, from 1885 to 1887. In addition to these stations within the limits of the two states there are others of great importance in defining the climates along the borders, viz., the first-order stations at Washington, Norfolk, Philadelphia, Harris-

[1] Abbe, C., The Meteorological Work of the U. S. Signal Service. U. S. Weather Bureau, Bull. No. 11. 8°. Wash., 1895, pp. 232-285.

burg and Atlantic City, and the second-order stations at Cape Henry and Cape May.

For many years almost the entire energy of the U. S. Weather Bureau was put into the development of dynamic meteorology, in storm, weather and flood predictions, in accordance with the original wording of the act establishing it. Later, agricultural interests demanded increasing attention, eventually resulting in the establishment of the present splendid system of state weather services, devoted mostly to the investigation of local climates, and the relation between climates and crops.

STATE WEATHER SERVICES.

In 1875 Professor Hinrichs, of Iowa, established the Iowa State Weather Service, receiving state aid. This was the first of a series of state weather and crop services soon to spring into existence in large numbers after many years of inactivity since the establishment of the New York state system in 1825, and the Pennsylvania system in 1837.

In 1881, during the administration of General Hazen, active measures were taken, at the suggestion of Professor Abbe, for the establishment of independent State Weather Services. This plan having been abandoned, General Hazen approved the plan of Major Dunwoody for the organization of state services as branches of the National Weather Bureau. Until 1887 the gathering of climatological statistics and the distribution throughout the states of the weather forecasts and special warnings issuing from the central office at Washington, formed the chief work of these state services. In 1887 the scope of the work was enlarged to take in the study of crop conditions in relation to the weather.

At the present time there are forty-five such services in existence in the states and territories, including Alaska, Porto Rico and Cuba. Some of these services were wholly supported by the state, some partially; others were controlled entirely by the National Bureau. Under the administration of Professor Moore, the present Chief of the Weather Bureau, nearly all of the state services have been brought entirely under the control of the National Bureau.

A feature of great importance, recently introduced by Professor Moore, is the establishment, in connection with the section centers, of a printing office, permitting the printing in unform style, of the yearly, monthly and weekly reports. By means of these reports the daily records of the weather at nearly 3,000 localities in our country are preserved in convenient form for study.

The services of the observers at these 3,000 stations are given free of cost to the government, but standard instruments and all necessary forms and stationery are supplied. The equipment of each station consists of a maximum and minimum self-registering thermometer and a rain-gauge. Observations are made once a day, and the record is sent to the section center at the close of each month.

In addition to this large corps of voluntary observers connected with the National Service through the state centers, there is a still larger body of crop correspondents. During the crop-growing season these correspondents, in number about 8,000, send to their respective section centers weekly reports on the condition of crops and state of the weather.

THE DELAWARE COLLEGE SUB-STATIONS, 1889-1899.

In 1888 a station was established at the Experiment Station in connection with Delaware College which reported to the National Bureau at Washington. In 1889 and 1890 several sub-stations in Delaware were equipped by Delaware College; in addition to reporting weekly to the Experiment Station, monthly reports are sent to the Maryland Section Center at Baltimore. These sub-stations were established under the supervision of Professor George A. Harter, who was succeeded in 1891 by Professor William Herbert Bishop. The latter continues to coöperate cordially with the Maryland Service.

THE MARYLAND STATE WEATHER SERVICE, 1891-1899.

The Maryland service was added to the list of state weather services in 1891. How it came to be organized, and its aims and methods, are described in detail in the introduction to this volume by the organizer and present Director, Professor Wm. Bullock Clark. A study of the climate of the state, based mostly upon the data col-

lected since 1892, is presented in succeeding pages by the Section Director and State Meteorologist, Mr. F. J. Walz.

The active stations in Maryland at present number 65; of crop correspondents there are about 175, the number varying considerably from season to season. Daily weather forecast flags are displayed at 25 places in the state; storm signals are hoisted at three points along the Bay, at Baltimore, Annapolis and Oxford.

In the bibliography is brought together a list of publications bearing upon the climate of Maryland. Most of these are publications of a more general character, but will be found to contain many valuable data relating to Maryland and Delaware.

The list of stations contains in detail the history of each station established in Maryland, Delaware and the District of Columbia wherever any record was found, from 1644 to May 1, 1899. Here are also brought together the stations having records of ten years or more and the period covered by observations. The longest record is that of Frederick, from 1821 to the present time; Washington has a record for about 76 years, and Baltimore for 75 years, but these are not continuous. A closer inspection of these station histories will bring out many interesting points; space will not permit of a more extended reference here, however. The stations for the special display of daily weather forecasts and for storm warnings are also shown in this list.

In the final lists are given the names of all observers and of all crop correspondents, at any time connected with the Maryland and Delaware stations of the National and State Weather Services or recording private observations.

The location of each of the active stations is shown on Plate XXXVII.

THE JOHNS HOPKINS UNIVERSITY AND METEOROLOGY, 1877-1899.

For many years there has been a cordial coöperation between the Johns Hopkins University and the U. S. Weather Bureau. The organization of a state weather service for Maryland under the supervision of the University was already discussed in 1877 by President Gilman and Professor Abbe. In 1882 the U. S. Weather Bureau

sent to the University Mr. Park Morrill to make a special study of problems of atmospheric electricity under the guidance of Professor Rowland. This work was continued at Baltimore until the fall of 1887. Observations of the potential of atmospheric electricity were regularly made during this period; during a portion of the time the record was photographic and continuous.

From time to time lectures on meteorology have been given under the auspices of the University. From 1889 to 1894 instruction in meteorology formed a part of the undergraduate course in Physical Geography, under the direction of Professor Wm. Bullock Clark. Professor Wm. M. Davis, of Harvard University, delivered a course of lectures to the students of this course in 1891; in the same year Professor Cleveland Abbe lectured before the Scientific Association.

In 1891 there grew out of the work in Physical Geography a meteorological bureau, which, soon after, by act of the General Assembly, became the Maryland State Weather Service, with headquarters at the University, and with Professor Clark of the Geological Department, as Director of the Service.

In 1897 instruction in meteorology was officially recognized as a part of the curriculum by the appointment of the writer as Instructor, and a year later Professor Abbe was appointed Lecturer in Meteorology. In the summer of 1898 Professor Abbe presented to the University his valuable special collection of books and pamphlets on meteorology, the library of a meteorologist and a lover of books collected during over thirty years of active and splendid service in the field of meteorology. The presence of this library will do much to encourage and promote the work of meteorology at the University.

Publications Relating to Meteorology in Maryland and Delaware.

Abbe, Cleveland, Sr. Recent contributions to meteorology.

J. H. Univ. Circulars, Baltimore, June, 1892, pp. 106-108.

Extract from an address before the Johns Hopkins University Scientific Association, Dec. 16, 1891.

——— Catalogue of recent meteorological works, serving as a nucleus for a special technical library.

J. H. Univ. Circulars, Baltimore, June, 1892, pp. 108-109.

ACWORTH, ALBERT E. Local weather sayings [Wicomico County].
Rep. Md. Weather Service, Baltimore, vol. ii, June, 1892, pp. 22-23.

——— Frosts in May at Mardela Springs and Princess Anne, Maryland.
U. S. Weather Rev., May, 1895, p. 172.

——— The Chesapeake peninsula.
Rep. Md. Weather Service, Baltimore, vol. v, Oct., 1895, pp. 39-40.
Agricultural and climatic features.

[ALEXANDER, JOHN HENRY]? Essay on the Indian summer.
Amer. Journ. Sci., New Haven, vol. xxvii, 1835, pp. 140-147.
Read at a meeting of the Maryland Academy of Science, by one of its members, Dec. 16, 1833.

ALEXANDER, JOHN HENRY. On a new form of mountain, or other barometer.
Amer. Journ. Sci., New Haven, vol. xlv, 1843, pp. 233-242.

BALTIMORE. Report of the engineer, Isaac Trimble, appointed by the Commissioners of the Mayor and City Council of Baltimore, on the subject of the Maryland Canal.
8°. Baltimore, 1837. 27 pp., 1 chart.
Contains monthly rainfall tables for Baltimore, 1817-24, by Lewis Brantz; for Germantown, Pa., from July, 1819—Dec., 1827, by Reuben Haines.

BELL, JOHN H. Practical illustration of the movements of hurricanes, with directions how they may be avoided.
8°. Baltimore, 1861. 88 pp., 2 pls.

BISHOP, W. H. See: Delaware College.

BLODGET, LORIN. On the distribution of precipitation in rain and snow, on the North American continent.
Proc. Amer. Assoc. Adv. Sci., 1853, pp. 101-108. Annals of Sci., Cleveland, vol. i, 1852-53, pp. 246-247.

——— Climate of the summer of 1853 in its relation to the agricultural interests of the United States.
8°. Washington, 1853. 38 pp.

——— Distribution of heat in the North American climate.
Edinb. N. Phil. Journ., vol. v, 1857, pp. 205-219. Annals of Sci., Cleveland, vol. i, 1852-53, pp. 247-248.

——— Climatology of the United States, and of the temperate latitudes of the North American continent, . . . with isothermal and rain charts for each season, the extreme months, and the year.

8°. Philadelphia, 1857. 536 pp., 13 pls.

Contains temperature and rainfall data for Baltimore, 1817-1854; for Annapolis, 1822, 1831-34, 1843-45; for Frederick, 1854-55; for Fort Washington, 1824-35, 1851-53, also rainfall for 1851, '52 and '53; for Schellman Hall (Sykesville), 1854-55. The discussions on climate also contain Maryland data.

——— The distribution of rain in the temperate latitudes of North America.

Edinb. N. Phil. Journ., vol. vi, 1857, pp. 93-103.

——— The climate of Maryland.

In: A new topographical atlas of Maryland, by Martenet, Walling & Gray. Baltimore, 1873. 1 p., 1 map.

Blome, Richard. A description of the island of Jamaica; with other isles and territories in America, to which the English are related.

12°. London, 1672. 192 pp.

Maryland, pp. 157-166.

Brantz, Lewis. Meteorological observations made in the vicinity of Baltimore during the years 1817 to 1824.

8°. Baltimore, 1818-25.

Daily observations made at 8 a. m., 2 p. m. and 10 p. m. Mean temperature, rainfall, character of day and prevailing direction of the wind. Monthly means bound with title page for each year. Summary partially reprinted in Rep. of the Md. Weather Service for Oct., 1891, p. 12.

——— The monthly mean temperature near Baltimore, from 8 years' observations, 1817-1824.

Amer. Almanac, 1834, p. 77.

——— Table of meteorological observations at Baltimore from January to December, 1836.

Trans. Md. Acad. Sci., Baltimore, vol. i, 1837. 12 pp.

Observation at 10 a. m., 3 p. m. and 7 p. m. daily. Temperature, pressure, wind, dew point, rainfall, and weather.

Brooke, Richard. A thermometrical account of the weather for one year, beginning September, 1753, kept in Maryland.

Phil. Trans. Roy. Soc., London, vol. li, pt. 1, 1759, pp. 58-69.

Daily a. m. and p. m. observations of temperature, wind direction and state of the weather.

——— A thermometrical account of the weather for three years [and five months] beginning September, 1754, as observed in Maryland.

Phil. Trans. Roy. Soc., London, vol. li, pt. 1, 1759, pp. 70-82.

The highest and lowest temperatures in each month are given, with occasional remarks on the weather and prevalent diseases.

CHANCELLOR, C. W. The climate of the Eastern Shore of Maryland considered with reference to its sanative and curative influence in pulmonary consumption and other diseases.

16°. Baltimore, 1889. 118 pp.

——— The Eastern Shore of Maryland as a health resort for consumptives.

Rep. Md. Weather Service, Baltimore, vol. ii, Sept., 1892, pp. 46-48. Reprint from: The Times and Register, Phila., Sept. 17, 1892.

——— The Medical climatology of Maryland.

Rep. Md. Weather Service, Baltimore, vol. iii, July, 1893, pp. 27-31.

CLARK, WILLIAM BULLOCK. Organization of the Maryland State Weather Service.

J. H. Univ. Circulars, Baltimore, June, 1891, p. 109. Rep. Md. Weather Service, Baltimore, vol. i, May, 1891, pp. 1-3.

——— Annual reports of the work of the Maryland State Weather Service.

In the Annual Reports of the President of the Johns Hopkins University for 1891-98. 8°. Baltimore, 1891-98.

——— Organization of the Maryland State Weather Service.

Rep. Md. Weather Service, Baltimore, vol. ii, April, 1892, pp. 1-2. Contains the Legislative bill establishing the Service.

——— Maryland State Weather Service. Report of progress.

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——— The leading features of Maryland climate.

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In: Maryland; its resources, industries and institutions. 4°. Baltimore, 1893, pp. 18-40. 1 pl.

——— Certain climatic features of Maryland.

Amer. Meteorol. Journ., Boston, vol. x, 1893-4, pp. 420-423.

——— For additional publications see: Maryland State Weather Service.

Clayton, John. A letter to the Royal Society, May 12, 1688. Giving an account of several observables in Virginia, more particularly concerning the air.

Phil. Trans. Roy. Soc., London, 1688. Also in: Force's Collection of hist. tracts, vol. iii, No. 12. 8°. Washington, 1844. 45 pp.

Collin, Nicholas. Observations made at an early period, on the climate of the country about the river Delaware. Collected from the records of the Swedish Colony by Nicholas Collin, Rector of the Swede's Church at Philadelphia.

Trans. Amer. Phil. Soc., Philadelphia, vol. i, 1818, pp. 340-352.

Contains references to the observations of John Campanius in 1644 and 1645, and to the records of later ministers of the Swedish Colony in the neighborhood of the present site of Wilmington, Delaware.

Coffin, James Henry. See: Smithsonian Institution.

Cronk, Corydon P. Some comparisons, climatic and otherwise.

Rep. Md. Weather Service, Baltimore, vol. ii, April, 1892, pp. 3-6.

The climate of Maryland in comparison with that of other places.

——— Statistics of Maryland weather.

Rep. Md. Weather Service, Baltimore, vol. iii, Sept., 1893, pp. 47-49.

——— Influence of forests on climate and agriculture.

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——— State Weather Service stations in Southern Maryland.

Rep. Md. Weather Service, Baltimore, vol. iv, July, 1894, pp. 17-18.

——— Observations taken at Frederick, Md., forty-three years ago by Dr. Lewis H. Steiner.

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——— See also: Maryland State Weather Service.

Davis, William Morris. Tornadoes; a story of a long inheritance.

J. H. Univ. Circulars, Baltimore, April, 1891, p. 78.

Read before the University Travellers' Club, Jan. 27, 1891.

——— An outline of meteorology.

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Abstract of six lectures delivered to the class in Physical Geography at the Johns Hopkins University in January, 1890.

DELAWARE COLLEGE, Newark, Delaware. Annual reports of the Meteorologist: Prof. George A. Harter from 1888 to 1890; Prof. W. H. Bishop from 1891 to 1898. An. Rep. Del. Experiment Station, Newark, 1888-1898.

Observations of the maximum and minimum thermometers, and the raingauge, at Newark, Seaford, Middletown, Dover, Milford, and Millsboro. At Newark and Seaford, observations of the barometer also.

DONALDSON, HENRY HERBERT. On the temperature sense.

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DONALDSON, J. H. Sharpsburg, Maryland, established as a meteorological station.

Rep. Md. Weather Service, Baltimore, vol. iv, Dec., 1894, pp. 59-60.

DUNWOODY, H. H. C. See: U. S. Weather Bureau.

DUVALL, GRAFTON. A history of the extraordinary season of 1804, and of the luxuriant vegetation, great rains and subsequent sickness in August, September and October, as they appeared near the river Monocasy and in the upper parts of Maryland.

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Md. Climate and Crops, Baltimore, Feb., 1899, pp. 6-7.

The blizzard of Feb. 10-13, 1899.

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Obl. 4°. [Washington, 1845.] 4 pp., 30 charts.

——— Second report on Meteorology [transmitted November 12, 1849]; third report [transmitted January 24, 1851].

Obl. 4°. [Washington, n. d.] 66 pp., 111 charts.

——— Message from the President of the United States, communicating, in compliance with a Resolution of the Senate of July 24, 1854, the Fourth Meteorological Report.

Sen. Ex. Doc. No. 65, 34th Cong., 3d Sess. 4°. Washington, 1857. 240 pp., 70 pls.

EVANS, LEWIS. A map of Pensilvania, New Jersey, New York, and the three Delaware counties [and the Eastern Shore of Maryland]. Published by Lewis Evans, March 25, 1749, according to act of Parliament.

The text on the face of the map contains the statement attributed to Benj. Franklin: "All our great storms begin to Leeward: thus a N. E. storm shall be a day sooner in Virginia than Boston . . . ."

FASSIG, OLIVER L. The heavy rainfall at Jewell, Anne Arundel County, July 26 and 27, 1897.

Md. Climate and Crops, Baltimore, Dec., 1897, p. 3.

14¾ inches of rain fell in 18 hours.

——— The establishment of twenty special stations of the Maryland State Weather Service.

Md. Climate and Crops, Baltimore, Jan., 1898, pp. 3-4.

——— A Maryland weather record for 1753 to 1757.

Md. Climate and Crops, Baltimore, Dec., 1898, pp. 3-4.

The observations of Dr. Richard Brooke of Prince George's County, Maryland.

——— See also: U. S. Weather Bureau.

FISHER, WILLIAM R. The aurora borealis of April 22, 1836.

Trans. Md. Acad. Sci., Baltimore, vol. i, 1837, pp. 165-167.

FORRY, SAMUEL. The climate of the United States and its endemic influences. Based chiefly on the records of the Medical Department and Adjutant-General's Office, U. S. Army.

8°. New York, 1842. 303 pp., 2 pls.

FREEMAN, T. J. A. A severe hail storm in Baltimore County [May 16, 1898].

Md. Climate and Crops, Baltimore, June, 1898, p. 3.

GRAY, F. A. See: Martenet, S. J., 1873.

GREEN, JAMES. [Description of the barometer made by James Green for the Maryland Academy of Science and Literature.]

Trans. Md. Acad. Sci., Baltimore, vol. i, 1837, pp. 138-142. 1 pl.

HAGERSTOWN. Der Volksfreund und Hägerstauner Calender. Gedruckt und zu haben von John Gruber, Hägerstown, Md.

Sm. 4°. Hagerstown, 1796-1899. 32 pp.

Issued for each year from 1797-1899. An English edition was issued for each year from 1822 to 1899. Contains "Conjectures of the weather" for each day of the year of issue; also "A table for foretelling the weather through all the lunations of each year."

——— The Hagerstown Town and Country Almanack. Printed and sold by John Gruber, Hagerstown, Md., annually from 1822 to 1899.

Sm. 4°. Hagerstown, 1821-99.

——— The National Union Hagerstown Almanack, for farmers and housekeepers. Published annually by the National Union Almanac Co.; O. Swingley, Business Manager. For the years 1887-99.

Sm. 4°. Baltimore, 1886-98.

Contains "Daily weather forecasts" for each day of the year of issue; also "A table for foretelling the weather for all the lunations of each year."

HARRINGTON, M. W. See: U. S. Weather Bureau.

HARTER, GEORGE A. See: Delaware College.

HENRY, ALFRED J. See: U. S. Weather Bureau.

HOLM, THOS. CAMPANIUS. Kort Beskrifning om Nya Sveriga. [Short account of New Sweden.]

4°. Stockholm, 1702.

Contains an account of the climate of the locality about the present site of Wilmington, Delaware, based upon daily observations upon the general character of the weather, made by his grandfather, Rev. John Campanius, in 1644 and 1645. Other records are also quoted. Extracts from the book may be found in the Transactions of the American Philosophical Society, Philadelphia, vol. i, 1818, pp. 340-352, in an article by Nicholas Collin.

HIGGINS, JAMES. A succinct exposition of the industrial resources and agricultural advantages of the State of Maryland.

8°. Annapolis, 1867. 112 pp. Doc. DD., House of Delegates of Mary-

Contains remarks upon the climate and healthfulness of Maryland.

HUNT, GEO. E. See: Md. State Weather Service.

KINSELL, E. G. Heavy rainfall in Washington County, Maryland, in August, 1887.

Md. Climate and Crops, Baltimore, Feb. 1898, pp. 3-4.

About 12 inches of rain fell in 3½ hours.

MALLORY, F. See WAIDNER, C. W.

MARTENET, S. J., WALLING, H. F., and GRAY, F. A. New topographic atlas of Maryland, with historical, scientific and statistical descriptions, and map of the United States.

4°. Baltimore, 1873.

Contains a climatological chart of Maryland, by Lorin Blodget.

MARYLAND ACADEMY OF SCIENCE AND LITERATURE. Report of the meteorological committee, consisting of Lewis Brantz, James Green, J. H. Alexander, William R. Fisher.

Trans. Md. Acad. Sci., Baltimore, vol. i, 1837, pp. 138-147, 1 pl. Also 8°. [Baltimore, 1837.] 8 pp.

Contains: Report of Mr. James Green on the construction of a barometer for the Acadamy, table of temperature corrections for barometric readings, hourly observations on certain term days in 1836 and 1837.

Maryland Board of World's Fair Managers. Maryland; its resources, industries and institutions. Prepared by members of Johns Hopkins University and others.

4°. Baltimore, 1893.

Chapter on climate, by W. B. Clark, pp. 18-40, 1 pl. Chapter on medical climatology, by C. W. Chancellor, pp. 40-47.

Maryland State Weather Service.

In coöperation with the Johns Hopkins University, the Maryland Agricultural College, and the U. S. Weather Bureau. Central Office at the Johns Hopkins University, Baltimore, Md. Organized in May, 1891. Established by Act of the General Assembly of Maryland, April, 1892.

Officers of the Service: Dr. William Bullock Clark, Johns Hopkins University, Director, 1891-99; Prof. Milton Whitney, Maryland Agricultural College, Secretary and Treasurer, 1891-99; Dr. Corydon P. Cronk, Meteorologist, 1891-May, 1896; George E. Hunt, Meteorologist, June, 1896-May, 1897; Ferdinand J. Walz, Meteorologist, June, 1897-1899.

All reports contain observations made at stations in Delaware and in the District of Columbia. The first monthly report issued was for May, 1891.

Organization of the Maryland State Weather Service.

Rep. Md. Weather Service, Baltimore, vol. ii, April, 1891, pp. 1-2.

Contains the Legislative Bill establishing the Service.

Preliminary statement [concerning the organization of the Service].

Rep. Md. Weather Service, Baltimore, May, 1891, pp. 1-3.

Crop reports.

Single sheets published weekly during the crop season from the organization of the Service, May, 1891, to September, 1896. Each report states the weather conditions during the week preceding the date of issue, and the condition of the staple crops. Published, in co-operation with the U. S. Weather Bureau, at Baltimore. For continuation of reports see U. S. Weather Bureau.

Monthly reports.

Vol. i, No. 1, May, 1891, to vol. i, No. 7, Nov., 1891. 8°. Baltimore, 1891. [2 to 12 pp. each.]

Vol. ii, No. 1, April, 1892, to vol. vi, No. 5, August, 1896. 4°. Baltimore. 1892-1896. [6 to 11 pp. each.]

The report for April, 1892, contains mean monthly values for Dec., 1891, to March, 1892, inclusive, during which period no reports were issued. For continuation of reports see: U. S. Weather Bureau.

Climatic charts of Maryland, including Delaware and the District of Columbia, together with a map showing the distribution of the geological and soil formations.

Baltimore, 1893. 11 charts and 3 pages of text. 33 in. by 21 in.

Annual and seasonal charts of temperature and rainfall.

The climatology and physical features of Maryland. First biennial report of the Maryland State Weather Service for the years 1892 and 1893. Dr. W. B. Clark, Director; Dr. C. P. Cronk, Meteorologist.

8°. Baltimore, 1894. 140 pp., 5 charts.

The [same]. Second biennial report, for the years 1894 and 1895.

8°. Baltimore, 1896. 111 pp., 5 charts.

For later publications see: U. S. Weather Bureau and Maryland State Weather Service.

MENDENHALL, T. C. Report of studies of atmospheric electricity.

Mem. Nat. Acad. Sci., Washington, vol. v, 1894, pp. 113-318.

Contains the Baltimore records of atmospheric electricity made at Johns Hopkins University from 1885 to 1887.

ROWLAND, H. A. On atmospheric electricity.

J. H. Univ. Circulars, Baltimore, Nov., 1882, pp. 4-5.

SCHOTT, CHARLES A. See: Smithsonian Institution.

SCOTT, JOSEPH. A geographical description of the states of Maryland and Delaware; also of the counties, towns, rivers, bays and islands, with a list of the hundreds in each county.

16°. Philadelphia, 1807. 191 pp.

Climate of Maryland, pp. 37-39.

SHRIVER, HOWARD. (*a*) Average temperature for each month at Cumberland, Md., from January, 1859, to December, 1898. (*b*) Maximum and minimum temperatures for each month from January, 1872, to December, 1898. (*c*) Rainfall for each month and year from January, 1872, to December, 1898.

8°. Single sheets privately printed.

——— The climate of Cumberland, Md.

Rep. Md. Weather Service, Baltimore, vol. v, August, 1895, pp. 21-22.

SMITH, JOHN. History of Virginia. The sixth voyage, 1606.
London, 1624. [Several editions.]

SMITHSONIAN INSTITUTION.

Tables and results of the precipitation, in rain and snow, in the United States. Discussed by Charles A. Schott.

Smithson. Contr. to Knowl. 4°. Washington, 1872. 175 pp., 8 pls. Second edition. 4°. Washington, 1881. 270 pp., 10 pls.

Contains tabulation and discussion of all Maryland rainfall data to 1874.

The winds of the globe; or the laws of atmospheric circulation over the surface of the earth. By James Henry Coffin, with a discussion and analysis of the tables and charts by Dr. Alexander Woeikof.

Smithson. Contr. to Knowl. 4°. Washington, 1875. 781 pp., 26 pls.

Contains tabulated results and discussion of data relating to the winds at all Maryland stations to 1869.

Tables, distribution and variations of the atmospheric temperature in the United States and some adjacent parts of America. Discussed under the direction of Joseph Henry, Secretary, by Charles A. Schott.

Smithson. Contr. to Knowl. 4°. Washington, 1876. 360 pp., 3 pls.

Contains a tabulation and discussion of all Maryland temperature observations from 1817 to 1870.

See also: U. S. Patent Office.

SWINGLEY, O. The hundred-year planetary almanac. For farmers and housekeepers. From 1876 to 1976.

8°. Baltimore, 1876.

TRIMBLE, ISAAC. See: Baltimore.

U. S. PATENT OFFICE AND SMITHSONIAN INSTITUTION. Results of meteorological observations made under the direction of the United States Patent Office and the Smithsonian Institution from the year 1854 to 1859 inclusive.

Vol. i, 4°. Washington, 1861. 1269 pp. Vol. ii, pt. 1, 4°. Washington, 1864. 545 pp.

Vol. ii, pt. 1, contains: Observations upon periodical phenomena in plants and animals, from 1851 to 1859, by E. B. Hough; storms of 1859, by Prof. J. H. Coffin.

——— Meteorology of 1863-1870. Compiled from reports made to the Smithsonian Institution by the U. S. Commissioner of Agriculture.

U. S. Agric. Rep., Washington, 1863-70.

UNITED STATES WAR DEPARTMENT: SURGEON-GENERAL'S OFFICE. Meteorological register for the years 1822-25, from observations made by surgeons of the Army at the military posts of the United States. Prepared under the direction of Joseph Lovell, Surgeon-General, U. S. Army.

8°. Washington, 1826. 63 pp.

—— The same, for the years 1826-30. Prepared under the direction of Thomas Lawson, Surgeon-General, U. S. Army, to which is appended the meteorological register for the years 1822-25.

8°. Philadelphia, 1840. 161 pp., 1 chart.

—— The same, for twelve years from 1831 to 1842 inclusive.

8°. Washington, 1851. 324 pp.

—— The same, for twelve years, from 1843 to 1854 inclusive.

4°. Washington, 1855. 775 pp., 10 charts.

U. S. WAR DEPARTMENT: SIGNAL SERVICE.

Weather Maps. January 13, 1871, to June 30, 1891.

Three maps per day issued from Jan., 1871, to Dec. 31, 1880, and from Jan. 1, 1887, to June 30, 1888; one map per day issued from Jan. 1, 1881, to Dec. 31, 1886; two maps per day issued from July 1, 1888, to June 30, 1891. For continuation see: U. S. Weather Bureau.

Annual reports, 1871 to 1891.

8°. Washington, 1871-1891.

Administrative reports, monthly and annual data and special articles. Also contain a reprint of the Monthly Weather Review from 1873 to 1883. For continuation see: U. S. Weather Bureau.

Daily bulletin of weather reports, taken at 7.35 A. M., 4.35 P. M., and 11.35 P. M., Washington mean time, with synopses, probabilities and facts. March, 1872, to June, 1877. [Printed monthly.]

8°. Wash., 1872 to 1877. (Oct. to Dec., 1875, not published.) The same. Sept., 1872, to Jan., 1875. Jan. to Dec., 1877, with tri-daily maps. Jan., 1878, to Dec., 1880, without maps. 4°. Wash., 1873, to 1882. Maps for 1878 printed later as Tri-daily Meteorological Record. Obl. 4°. Wash., 1884.

The weekly weather chronicle.

4°. Washington, Sept., 1872, to April, 1881. 2 pp. each.

Monthly weather review. January, 1873, to June, 1891.

4°. Washington, 1873-91.

Annual summary with volume for 1890. For continuation see: U. S. Weather Bureau.

Farmers' bulletin, synopses and probabilities. March 24, 1873, to December 31, 1880.

4°. Washington, 1873, to 1880.

Daily.

The Meteorological record.

Sheets issued daily from Jan. 1, 1874, to July 24, 1875. Merged in the Bulletin of international meteorological observations.

Bulletin of international meteorological observations.

4°. Washington, 1875 to 1891.

From Jan. 1, 1875, to June 30, 1884, printed daily; from July, 1884, to Dec., 1887, printed monthly as: Summary and review of international meteorological observations; from Jan., 1888, to June, 1889, printed semi-annually.

[GREELY, A. W.] Chronological list of auroras observed from August 1, 1873, to December 31, 1875, which have been reported to the Chief Signal Officer of the Army.

In Rep. U. S. Sig. Service, Washington, 1880, pp. 1096-1115.

Professional Papers.

No. 2. GREELY, A. W. Isothermal lines of the United States.

4°. Washington, 1881. 1 p., 12 pls.

No. 3. ——— Chronological list of auroras observed from 1870 to 1879.

4°. Washington, 1881. 76 pp.

No. 7. FINLEY, J. P. Report on the character of six hundred tornadoes.

4°. Washington, 1884. 29 pp., 3 charts.

No. 9. DUNWOODY, H. H. C. Charts and tables showing geographical distribution of rainfall in the United States.

4°. Washington, 1883. 29 pp., 3 charts.

No. 10. Tables of rainfall and temperature compared with crop production.

4°. Washington, 1882. 15 pp.

No. 14. FINLEY J. P. Tornado studies for 1884.

4°. Washington, 1885. 15 pp.

Absolute humidity and mean cloudiness in the United States represented by tables and charts. By H. H. C. Dunwoody.

Ann. rep. Chief Signal Officer, Washington, 1884, pp. 128-137, 8 charts.

Tri-daily chart, illustrating the storm of January 6-10, 1886.
Washington, 1886. 14 charts.

Notes.

No. 17. MORRILL, PARK. A first report upon observations of atmospheric electricity at Baltimore, Md.
8°. Washington, 1884. 8 pp., 6 charts.

No. 18. MCADIE, ALEX. The aurora in its relations to meteorology.
8°. Washington, 1885. 21 pp., 14 charts.

No. 20. HAZEN, H. A. Thunderstorms of May, 1884.
8°. Washington, 1885. 8 pp., 2 charts.

No. 23. WOODRUFF, T. M. Cold waves and their progress.
8°. Washington, 1885. 21 pp.

Weather conditions of wheat, cotton, corn and tobacco districts. May 7, 1887, to October 4, 1889.
Fol. Washington, 1887-89.

The weather crop bulletin. May 1, 1887-June 30, 1891.
Issued weekly during the growing season; at other times monthly.
For continuation see: U. S. Weather Bureau.

Charts showing the rainfall in the United States for each month from January, 1870, to December, 1873.
4°. Washington, 1888. 48 charts.

Tri-daily weather charts of the Signal Service, illustrating the severe storm of March 11-14, 1888.
Extract from the Monthly Weather Review for March, 1888, with charts added.

Charts showing the normal monthly rainfall in the United States.
4°. Washington, 1889. 12 pp., 13 charts.
Extracted from the Monthly Weather Review with notes and tables.

Floods in the Middle Atlantic States, May 31 to June 3, 1889.
4°. Washington, 1889, 5 pp., 4 charts.
Extracts from the Monthly Weather Review for May and June, 1889.

General instructions relative to the co-operation of the U. S. Signal Service with State Weather Services.
8°. Washington, 1889. 13 pp.

Daily international charts. October 1, 1886, to December 31, 1887; July 1, 1884, to December 31, 1884.

Fol. Washington, 1889, 1891.

Index of meteorological observations in the United States from the earliest records to January, 1890. Compiled in the Records Division, U. S. Signal Office.

Obl. 4°. Washington, 1891. Milliographed.

Charts showing the "probability of rainy days." Prepared from observations for eighteen years.

Fol. Washington, 1891. 12 charts, 16 in. by 22 in.

Charts showing the average monthly cloudiness in the United States.

Fol. Washington, 1891. 12 charts.

Charts showing the isobars, isotherms and winds in the United States for each month from January, 1871, to December, 1873.

4°. Washington, 1891. 36 charts.

Charts showing average velocity and direction of the wind, prepared from observations for seventeen years.

Washington, 1891. 36 charts, 16 in. by 22 in.

Charts showing maximum and minimum temperatures by decades for all years.

Washington, 1891. 37 charts, 16 in. by 22 in.

International monthly charts of mean pressures and wind velocities for 1882 and 1883.

Fol. Washington, 1891. 24 charts.

U. S. DEPARTMENT OF AGRICULTURE: WEATHER BUREAU.

Monthly Weather Review. July, 1891-1899. With annual supplements from 1890.

4°. Washington, 1891-1899.

Climate and crop reports. Issued weekly from April to September, and monthly from October to March.

Fol. sheets. Washington, 1891-1899.

Weather maps.

Washington, 1891-99.

Sheets 16 by 22 in. From 1891 to 1896 two charts per day; from 1896 to 1899 one chart per day.

Bulletin No. 4. Some physical properties of soils in their relation to moisture and crop distribution. By Milton Whitney.

8°. Washington, 1892. 90 pp.

Maryland data used in discussions.

Bulletin A. Meteorological summary of international observations. By Major H. H. C. Dunwoody.

Washington, 1893. 12 pp., 55 charts, 16 by 22 in.

Snow charts, published weekly during the winter, showing the amount of snow on the ground on Mondays at stations of the Weather Bureau. Single sheets.

Washington, 1893-99.

Annual reports of the Chief of the Weather Bureau to the Secretary of Agriculture, 1891-1897.

4°. Washington, 1893-99.

Contain tabulated data and special contributions.

Bulletin No. 11. Report of the International Meteorological Congress held at Chicago, Ill., August 21-24, 1893. Edited by Oliver L. Fassig, Secretary. Parts I, II, III.

8°. Washington, 1894-96.

Part II, Section IV, relating to history and bibliography, contains a series of articles on the history of meteorology in the United States, in which reference is made to the meteorological systems in operation in Maryland.

Special storm charts.

Washington, 1893-1898.

Charts illustrating severe or destructive storms or cold waves, and issued within a few days after the occurrence of the storm. The series comprises charts of the following storms which passed over Maryland and Delaware: The coast storms of Oct. 5-14, 1893; the inland storms of Dec. 14-16, 1893, and May 17-18, 1894; the West Indian hurricanes of Sept. 24-29, and of Oct. 8-10, 1894; the cold wave storm of Feb. 5-8, 1895; the Gulf storm of Nov. 25-26, 1895; the cold wave storm of January 2-5, 1896; the coast storm of Feb. 5-7, of March 10-12, of March 16-20, 1896; the West Indian hurricane of Sept. 29-30, 1896; the inland storm of Jan. 24-26, 1898.

Bulletin C. Rainfall and snow of the United States, compiled to the end of 1891, with annual, seasonal, monthly and other charts. By Mark W. Harrington.

Text 4°. Washington, 1894. 80 pp. Atlas of 23 charts, 16 by 22 in.

Climate and Health. A summary of statistics for each week in the month. July, 1895, to March, 1896.

4°. Washington, 1895-96.

Statistics of State Weather Services. By Oliver L. Fassig.

Extract from Monthly Weather Review of June, 1895. Also printed separately. 8°. Washington, 1896. 12 pp.

Bulletin D. Rainfall of the United States, with annual, seasonal and other charts. Prepared by Alfred J. Henry.

4°. Washington, 1897. 58 pp., 14 charts.

U. S. Weather Bureau and Maryland State Weather Service.

Crop bulletins of the Maryland and Delaware Section of the U. S. Climate and Crop Service.

Single sheets issued weekly during the growing season. Baltimore, Sept., 1896-99.

For earlier series see: Maryland State Weather Service.

Annual summary of the Maryland and Delaware Section of the Climate and Crop Service, U. S. Weather Bureau, in coöperation with the Maryland State Weather Service for the years 1896, 1897, 1898.

4°. Baltimore, 1897-99. 12 pp. each.

For earlier numbers see: Maryland State Weather Service.

Monthly reports of the Maryland and Delaware Section of the Climate and Crop Service, U. S. Weather Bureau, in coöperation with the Maryland State Weather Service. Vol. i, No. 1, September, 1896, to vol. iv, 1899.

4°. Baltimore, 1896-99. 8 pp. each.

For earlier numbers see: Maryland State Weather Service.

Van Bibber, W. C. The climate of the greater Piedmont and mountainous regions of the southern United States.

Climatologist, Philadelphia, vol. ii, 1892, pp. 18-28.

Waidner, C. W., and Mallory, F. A comparison of Rowland's mercury thermometers with a Griffith's platinum thermometer.

J. H. Univ. Circulars, June, 1897, pp. 42-43.

Walling, H. F. See: Martenet, S. J., 1873.

Walz, Ferdinand Jackson. Voluntary meteorological and crop reporting stations [of the Maryland and Delaware Section of the U. S. Climate and Crop Service].

Md. Climate and Crops, Baltimore, April, 1898. Also published separately. 12°. Baltimore, 1898. 3 pp.

——— Studies of climate.

Md. Climate and Crops, Baltimore, Nov., 1898, pp. 3-4.

An outline for the study of local climates.

——— The destructive storm of December 4, 1898.

Md. Climate and Crops, Baltimore, Jan., 1899, pp. 3-4.

——— Weather Bureau work at Baltimore.

The Newsletter, J. H. Univ., Baltimore, February 14, 1899. Md. Climate and Crops, Baltimore, March, 1899, pp. 3-4.

WHITNEY, MILTON. On the structure and some physical properties of soils.

J. H. Univ. Circulars, Baltimore, June, 1891, pp. 123-125.

Abstract of a paper read before the Scientific Society of Johns Hopkins University.

——— Soil investigations.

Fourth An. Rep. Md. Agric. Exp. Station, College Park, 1891, pp. 249-296.

Investigations carried on in co-operation with the Johns Hopkins University on the Clifton estate.

——— Soil investigations at Clifton [Baltimore County].

Rep. Md. State Weather Service, Baltimore, vol. ii, May, 1892, pp. 13-15.

——— Relation of soils to meteorological conditions and to crop production.

Rep. Md. State Weather Service, Baltimore, vol. ii, Jan., 1893, pp. 77-79.

——— Soils of Maryland.

Rep. Md. State Weather Service, Baltimore, vol. iii, June, 1893, pp. 15-22.

——— See also: U. S. Weather Bureau.

[ANON.] A winter tornado in Maryland, February 10 [1887].

Amer. Meteorol. Journ., Ann Arbor, vol. iii, 1886-87, pp. 498-501. From the Baltimore Sun.

[ANON.] Climatological work at Johns Hopkins Hospital, Baltimore.

Amer. Meteorol. Journ., Ann Arbor, vol. vi, 1889, pp. 275-277.

Meteorological Stations.

Nearly all meteorological observations in Maryland, Delaware and the District of Columbia were made under the auspices of some organization or institution. The instrumental equipment and hours of observation were in the main uniform in each system, so that a simple reference to the system to which each station belonged suffices to indicate the kind of observations and the hours at which they were made. Reference to the bibliographical section will show in what publication a summary of the observations may be found.

[S. G. O.]—The system of the Surgeon-General's Office of the Army Medical Department. Observations included readings of the barometer, thermometer, hygrometer, the raingauge, of the direction and force of the wind, and of state of the weather. The hours of observation were in the main at 7 a. m., 2 p. m. and 9 p. m.

[S. I.]—The system of the Smithsonian Institution. Observations at a regularly equipped station included readings of the thermometer, the hygrometer, the raingauge, observations of the direction and force of the wind and of the state of the weather. The hours of observation were 7 a. m., 2 p. m. and 9 p. m.

[U. S.]—The system of the U. S. Weather Bureau. The character of the observations and the hours of observation are indicated in connection with each of the regular U. S. Weather Bureau stations. At stations of the voluntary observers the system of the Smithsonian Institution was continued until 1888, consisting of three observations daily. For a few succeeding years the observations were made at 8 a. m. and 8 p. m. Later the exposed thermometers were replaced by maximum and minimum thermometers.

[Md.]—The system of the Maryland State Weather Service. Each station is equipped with a maximum and minimum thermometer, and a raingauge. The prevailing direction of the wind and state of the weather are noted daily in addition to unusual weather conditions. In addition certain stations are equipped with maximum solar radiation and minimum terrestrial radiation thermometers.

[Del.]—The system of the Delaware College Experiment Station at Newark, Delaware. The instrumental equipment comprises a maximum and a minimum thermometer and a raingauge.

In all cases where additional instruments are read, not included in the regular equipment, a note to this effect will be found in connection with the station record.

*—Active stations.

MARYLAND.

Annapolis, Anne Arundel County. 38° 59′, 76° 30′. 50 ft.

President H. Humphrey, St. Johns College.

Reported at intervals to the Franklin Institute, Philadelphia, in 1838. Barometer, thermometers and raingauge.

ANNAPOLIS, Anne Arundel County. 38° 59′, 76° 30′. 20 ft.

POST SURGEON, U. S. Army, Fort Severn. 1822, 1831-34, 1843-45. [S. G. O.]
For continuation see: Annapolis, U. S. Naval Academy.

ANNAPOLIS, Anne Arundel County. 38° 59′, 76° 30′. 20 ft.

U. S. NAVAL ACADEMY, MEDICAL INSPECTORS, DRS. A. ZUMBROCK, WILLIAM R. GOODMAN, M. DUVAL, A. C. GORGAS. Nov., 1855-59, 1861-June, 1876. To April, 1874 [S. G. O.]; May to Sept., 1874 [S. I.]; Oct., 1874, to June, 1876 [U. S.]

Barometric observations from 1874 to 1876.

*ANNAPOLIS, Anne Arundel County. 38° 59′, 76° 30′. 45 ft.

J. E. ABBOTT. June, 1894-99. [Md.] [U. S.]

*BACHMAN'S VALLEY, Carroll County. 39° 37′, 76° 55′ 860 ft.

JOHN MILLER MYERS (P. O. Westminster). Sept., 1893-99. [Md.] [U. S.]
Thermometer read at 7 a. m., 2 p. m. and 9 p. m. until Aug., 1895.

BALTIMORE, west part of city. 39° 17′, 76° 37′. 80 ft.

CAPT. LEWIS BRANTZ. 1817-24, Jan. to Aug., 1829, Nov., 1836, to June, 1837.

Temperature, rainfall, winds, and clouds observed daily at 8 a. m., 2 p. m. and 10 p. m. Barometer and hygrometer added in 1836. Results published in pamphlet form from 1818 to 1825; reprinted in the American Almanac, 1834, p. 77.

BALTIMORE. 39° 16′, 76° 35′. 36 ft.

FORT MCHENRY, Post Surgeons, U. S. Army. 1831 to June, 1859, April, 1861, to Jan., 1862, 1864 to Feb., 1892. [S. G. O.]

BALTIMORE. 39° 17′, 76° 36′. 53 ft.

MARYLAND ACADEMY OF SCIENCE AND ARTS.

Hourly observations of the barometer, thermometers, hygrometer, of wind direction and velocity, of cloud movement, and of the state of the weather, during the following special "term days": 1836, 21st and 22nd of June, Sept. and Dec.; 1837, 21st and 22nd of March.

BALTIMORE. 39° 18′, 76° 38′. 193 ft.

DR. T. EDMONDSON, JR. 1835-37; 1846 to Oct., 1853.

Temperature and rainfall observations. Printed copies of reports for Jan., March, July and Aug., 1836, presented to Md. Acad. of Science.

BALTIMORE. 39° 17′, 76° 37′. 50 ft.

DR. G. S. SPROSTON, U. S. N. 1835-36.

Occasional reports to the Franklin Institute, Philadelphia.

BALTIMORE. 39° 17′, 76° 37′. 50 ft.

DR. A. ZUMBROCK. Apr. 1850 to July, 1852. [S. I.]

BALTIMORE. 39° 18′, 76° 37′. 50 ft.
PROFESSOR ALFRED M. MAYER. Nov., 1857, to Aug., 1859. [S. I.]

*BALTIMORE. 39° 18′, 76° 36′. 112 ft.
WILLIAM LUTHER WOODS, Johns Hopkins Hospital. Nov., 1894-99. [Md.] [U. S.]

*BALTIMORE. 39° 18′, 76° 37′. 123 ft.
U. S. WEATHER BUREAU (U. S. Signal Service until July 1st, 1891). Jan., 1871 to 1899. First order station. Continuous records of pressure, temperature, wind direction and velocity, rainfall and sunshine. Continuous record of wind direction and velocity since 1871; of pressure and temperature since 1893; of rainfall and sunshine since 1894. Eye observations three times daily from 1870 to Feb., 1886; five observations daily from March, 1886, to July, 1886; three observations daily from Aug., 1886, to June, 1888; two observations daily from July, 1888, to date. [U. S.]
Observations of atmospheric electricity from 1882-87.

*BALTIMORE, Suburb of, Walbrook. 39° 18′, 76° 38′. 200 ft.
F. J. WALZ, Walbrook, March, 1898-99. Temperature only. [Md.]

BARRON CREEK SPRINGS. See: Mardela Springs.

BEL ALTON, Charles County. 38° 28′, 76° 59′. 150 ft.
WALTER COX. Aug., 1894, to June, 1895. [Md.]

BEL AIR, Harford County. 39° 32′, 77° 40′. 350 ft.
J. LAWRENCE MCCORMICK. May to Aug., 1898.
Rainfall observations only. Records sent to the Division of Soils, U. S. Department of Agriculture.

BENEDICT, Charles County. 38° 31′; 76° 41′. 15 ft.
THOMAS BERRY. April, 1893, to Sept., 1894. [Md.]

*BERLIN, Worcester County. 38° 20′, 75° 13′. 38 ft.
DR. E. J. DIRICKSON, March to June and Oct., 1898. [Md.]
Max. insolation, and min. radiation thermometers.

BETTERTON, Kent County. 39° 23′, 76° 5′. 80 ft.
EDWARD E. CAREY. March-July, 1898. [Md.]

BLADENSBURG, Prince George's County. 38° 57′, 76° 56′. 105 ft.
BENJAMIN O. LOWNDES. Dec., 1854, to Aug., 1865. [S. I.]

*BLUE MOUNTAIN HOUSE, Washington Co. 39° 34′, 77° 31′. 1200 ft.
JOHN GIBBONS. March and April, 1899. [Md.]

*Boettcherville, Allegany County. 39° 39′, 78° 48′. 780 ft.
Francis Frederick Brown. 1891 to 1899. From 1891 to May 1, 1896, thermometer read at 7 a. m. and 2 p. m. From May, 1896, to Oct., 1897, wet and dry bulb. From Nov., 1897, to date, max. and min. therm. Raingauge from 1891-99. [Md.] [U. S.]

*Boonsboro (1), Washington County. 39° 31′, 77° 38′. 600 ft.
Charles E. Huntzbery. February, 1898-99. [Md.]
Max. insolation and min. radiation thermometers, June to July, 1898.

*Boonsboro (2), Washington County. 39° 32′, 77° 39′. 800 ft.
Samuel Lafayette Ford. Jan., 1898-99. [Md.]
Max. insolation and min. radiation thermometers during April and May, 1898.

Bryantown, Charles County. 38° 33′, 76° 51′. 140 ft.
B. M. Edelen, Jr. Jan., 1892. [Md.]

Burkittsville, Frederick County. 39° 24′, 77° 40′. 600 ft.
J. Paul Slifer. Oct., 1894, to April, 1895; Feb. to April, 1896. [Md.]

Cambridge, Dorchester County. 38° 34′, 76° 5′. 25 ft.
Calvert Orem. Jan., 1893, to Feb., 1894. [Md.]

Cambridge, Dorchester County. 38° 34′, 76° 5′. 25 ft.
Jas. S. Sheppard. Oct., 1895, to July, 1896. [Md.]

*Cambridge, Dorchester County. 38° 34′, 76° 5′. 25 ft.
J. A. Jordan. March, 1899. [Md.] [U. S.]

Catonsville, Baltimore County. 39° 17′, 76° 44′. 500 ft.
St. Timothy's Hall, G. S. Grape and others. Dec., 1865, to Feb., 1868. [S. I.]
Record incomplete.

*Charlotte Hall, St. Mary's County. 38° 28′, 76° 47′. 167 ft.
R. W. Sylvester. Jan., March, April, 1892. Major G. M. Thomas, June and July, 1893. Prof. J. Francis Coad, Oct., 1893-99. [Md.] [U. S.]

*Chase, Baltimore County. 39° 22′, 76° 23′. 25 ft.
John Wilson Crouch. Feb., 1898-99. [Md.]
Max. insolation and min. radiation thermometers since April, 1898.

Chase, Baltimore County. 39° 22′, 76° 22′. 20 ft.
William H. Evans. Feb. and March, 1898. [Md.]

CHERRYFIELDS, St. Mary's County. 38° 12′, 76° 32′. 7 ft.
J. EDWIN COAD, P. O. Valley Lee. Oct., 1893, to Jan., 1899. [Md.] [U. S.]
Observations at 8 a. m. and 8 p. m.

CHESTERTOWN, Kent County. 39° 13′, 76° 4′. 85 ft.
WASHINGTON COLLEGE, PROF. J. R. DUTTON; PROF. F. L. BARDEEN. June, 1855, to July, 1864; 1880-95.
Record incomplete. No observations during 1860, and during most of 1856 and 1857. From 1855-64 [S. I.]. From 1880-95, private record.

*CHESTERTOWN, Kent County. 39° 13′, 76° 5′. 80 ft.
HON. MARION DE KALB SMITH. Nov., 1893-99. [Md.] [U. S.]

*CHEWSVILLE, Washington County. 39° 38′, 77° 38′. 530 ft.
E. INGRAM OSWALD. Feb., 1898-99. [Md.]
Max. insolation and min. radiation thermometers since May, 1898.

CLEAR SPRING (1), Washington County. 39° 39′, 77° 56′. 500 ft.
W. E. LOOSE, JR. Feb., 1898, to Oct., 1898. [Md.]
Max. insolation and min. radiation thermometers during March and April.

*CLEAR SPRING (2), Washington Co. (Laurel Hill). 39°40′,77°56′. 650 ft.
WILLIAM WALLACE FRANTZ. Feb., 1898-99. [Md.]
Max. insolation and min. radiation thermometers during April and May.

*COLEMAN, Kent County. 39° 22′, 76° 7′. 80 ft.
JAMES SHEPPARD HARRIS. Feb., 1898-99. [Md.]
Max. insolation thermometer since April, 1898, and min. terrestrial radiation thermometer since Nov., 1898.

COLLEGE PARK, Prince George's County. 38° 58′, 76° 57′. 170 ft.
DR. C. M. JONES, Md. Agricultural College. Feb., 1861 to Feb., 1862; July, 1862. [S. I.]

*COLLEGE PARK, Prince George's County. 38° 58′, 76° 57′. 170 ft.
PROF. HARRY JACOB PATTERSON, Md. Agricultural College. July, 1888-99. [Md.] [U. S.]
Draper's self-recording thermometer.

CUMBERLAND, Allegany County. 39° 39′, 78° 46′. 700 ft.
T. L. PATTERSON. 1840.
Rainfall observations for about one year in connection with the construction of the Chesapeake and Ohio Canal.

CUMBERLAND, Allegany County. 39° 39′, 78° 46′. 700 ft.
EDWIN THOMAS SHRIVER. Jan., 1859, to Jan., 1896. [S. I.] [Md.]

From 1859 to 1871 thermometer read at 7 a. m.; from 1871 to 1896 wet and dry thermometers and raingauge read at 7 a. m., 2 p. m. and 9 p. m. Barometer observations during 1883 and 1884. Observations continued by Webster Bruce, *q. v.*

CUMBERLAND, Allegany County. 39° 39′, 78° 46′. 700 ft.
WEBSTER BRUCE. April, 1896, to March, 1897. [Md.]
Continuation of series of observations by Mr. E. T. Shriver, *q. v.*

*CUMBERLAND, Allegany County. 39° 39′, 78° 46′. 725 ft.
HOWARD SHRIVER. May, 1889-99. [Md.] [U. S.]
Barometer, wet and dry-bulb thermometers. Draper's self-recording thermometer, raingauge.

*DARLINGTON, Harford County. 39° 38′, 76° 13′. 300 ft.
PROF. A. F. GALBREATH, Darlington Academy. Oct., 1891-99. [Md.] [U. S.]

DEER PARK, Garrett County. 39° 25′, 79° 20′. 2500 ft.
GEORGE W. HARRISON. Aug. to Nov., 1880. [U. S.]
Thermometer read at sunset; wind direction recorded at 2 p. m.

DEER PARK, Garrett County. 39° 25′, 79° 20′. 2500 ft.
L. H. SCHOOLFIELD. Dec., 1880, to March, 1881; Jan. to March, 1882. [U. S.]
Wet and dry-bulb thermometers, barometer, and raingauge. Observations at 7 a. m., 2 p. m. and 9 p. m.

*DEER PARK, Garrett County. 39° 26′, 79° 20′. 2457 ft.
S. P. SPECHT. Oct., 1894-99. [Md.] [U. S.]

*DENTON, Caroline County. 38° 54′, 75° 49′. 42 ft.
F. C. RAMSDELL. Dec., 1891-99. [Md.] [U. S.]
Record incomplete.

*EASTON, Talbot County. 38° 45′, 76° 5′. 20 ft.
CAPT. JACOB G. MORRIS, Miles River Neck. 1867-99.
Mr. Morris has kept a record of min. temperature since 1867, and a record of max. temperature since 1888. A private record.

EASTON, Talbot County. 38° 46′, 76° 5′. 35 ft.
S. P. MINNICK and GEORGE W. MINNICK. Nov., 1891, to May, 1895. [Md.] [U. S.]

*EASTON, Talbot County. 38° 46′, 76° 5′. 35 ft.
HENRY SHREVE. June 1, 1894-99. [Md.] [U. S.]

EDGEMONT, Washington County. 39° 41′, 77° 33′. 750 ft.
CHARLES FELDMAN. Aug., 1892, to April, 1893.

ELKTON, Cecil County. 39° 37′, 75° 50′. 40 ft.

F. FINCH. Dec., 1843, and July, 1844.

Temperature, rainfall and winds observed at sunrise, 9 a. m., 3 p. m. and 9 p. m. Reports probably sent to the Franklin Institute in Philadelphia.

*ELLICOTT CITY, Howard County. 39° 17′, 76° 53′. 500 ft.

ST. CHARLES COLLEGE. Nov., 1871, to April, 1873; April, 1895-99. [S. I.] [U. S.] [Md.]

From 1895 to May, 1897, observations made by Rev. H. M. Chapuis, S. S.; since 1897, by Rev. George Lewis Harig, S. S. Records not continuous.

EMMITSBURG, Frederick County. 39° 41′, 77° 21′. 720 ft.

MT. ST. MARY'S COLLEGE, PROF. ELDER. 1838 and 1839.

Prof. Elder kept a journal of the weather during March, 1838, and at other times. Probably reported to the Franklin Institute.

*EMMITSBURG, Frederick County. 39° 41′, 77° 21′. 720 ft.

PROF. GIRAUD and F. G. HOOVER, 1843.

Occasional reports sent to Prof. Espy, U. S. Navy Department, Washington, D. C.

EMMITSBURG, Frederick County. 39° 41′, 77° 21′. 720 ft.

MT. ST. MARY'S COLLEGE. 1866 to Nov., 1873; Sept., 1875, to Jan., 1888; Feb., 1888-99. [U. S.] [Md.]

Barometric observations. DR. JAMES A. MITCHELL, 1888-99. Earlier observers: Prof. Eli Smith, 1866; Prof. Charles H. Jourdan, 1867-72; Augustus Reudter, T. Carmody, A. F. Dorley, 1873-88; record not continuous.

*FALLSTON, Harford County. 39° 31′, 76° 24′. 450 ft.

PROFESSOR G. G. CURTISS, Fallston School. Bagley P. O. Sept., 1870-99. [S. I.] [U. S.] [Md.]

Barometric observations. Since Sept., 1894, most of the observations have been made by J. H. Curtiss. Private instruments with the exception of the max. and min. thermometers.

FEDERALSBURG, Caroline County. 38° 42′, 75° 48′. 34 ft.

A. H. BOIES. Oct., 1881, to May, 1882. [U. S.]

FENBY, Carroll County. 39° 32′, 77° 0′. — ft.

WILLIAM FENBY. Dec., 1892, to Nov., 1894.

Exposed thermometer and raingauge. Private instruments.

FLINTSTONE, Allegany County. 39° 42′, 78° 36′. 800 ft.

NEWTON T. DOWNS, Feb. to May, 1896. JUSTIN BARKMAN, June, 1896, to April, 1898. [Md.]

FORT FOOTE, Prince George's County. 38° 47′, 77° 0′. 150 ft.

U. S. POST SURGEON, DR. JOHN W. BAYNE. July, 1871, to Oct., 1878. [S. G. O.]

FORT WASHINGTON, Prince George's County. 38° 42′, 77° 2′. 100 ft.

U. S. POST SURGEON. 1824-35, 1851-53, 1868-72. [S. G. O.]

*FREDERICK, Frederick County. 39° 24′, 77° 24′. 275 ft.

Several observers. About 1821 to 1899. From Feb., 1836, to 1899 the record is continuous, and consists of the temperature observed uniformly at sunrise, for a time at sunrise and sunset, for a time at sunrise, noon and sunset; also the state of the weather, remarkable rains, snows and storms. The record from 1836 to date is in the possession of Mr. Allan G. Quynn, of Frederick. Observations made at the hardware store of A. G. Quynn and Co. Observers: Jacob Sahm, 1836-58; Henry Koehler, 1858-59; Jacob Sahm, 1859-68; Wm. H. Zeigler, 1868-75; Caspar Quynn, 1875-99.

FREDERICK, Frederick County. 39° 24′, 77° 24′. 275 ft.

DR. LEWIS H. STEINER. Aug., 1851-59. [S. I.]

FREDERICK, Frederick County. 39° 24′, 77° 24′. 275 ft.

HENRY E. HENSHAW, MISS H. M. BAER, J. K. HENSHAW. 1854-59, Jan., 1861, to April, 1872. [S. I.]

*FREDERICK, Frederick County. 39° 24′, 77° 24′. 275 ft.

MCCLINTOCK YOUNG. Jan., 1889, to Feb., 1892; July, 1894-99. [U. S.] [Md.]

FREDERICK, Frederick County. 39° 24′, 77° 24′. 275 ft.

WOMAN'S COLLEGE. PRES. APPLE, G. E. BANTZ, W. A. LANTZ and others. March, 1892, to May, 1896. [Md.]

Records not continuous.

*FROSTBURG, Allegany County. 39° 39′, 78° 56′. 2100 ft.

MR. and MRS. G. G. TOWNSEND. June, 1898-99. [Md.] [U. S.]

GAITHERSBURG, Montgomery County. 39° 8′, 77° 12′. 516 ft.

J. T. DE SELLUM, Summit Hall. May to Sept., 1871; May, 1888, to Aug., 1891. [S. I.] [U. S.]

Temperature only.

GALENA, Kent County. 39° 20′, 75° 55′. 60 ft.

HENRY PARR. Sept., 1888, to June, 1890. [U. S.]

GAMBRILL'S, Anne Arundel County. 39° 4′, 76° 40′. 160 ft.

JAMES E. MOGUE. Sept. to Dec., 1888; July, 1889, to March, 1890. [U. S.]

GARRISON, Baltimore County. 39° 24′, 76° 46′. 500 ft.

A. W. NYCE. March to Aug., 1895. [Md.]

GLEN BURNIE, Anne Arundel County. 39° 10′, 76° 38′. 60 ft.
CHARLES PUMPHREY. May to Aug., 1898.
Rainfall only; reports sent to Division of Soils, U. S. Department of Agriculture.

GLYNDON, Baltimore County. 39° 28′, 76° 48′. 700 ft.
JOHN A. JOHNSON. Aug., 1878, to Aug., 1879; May to June, 1881. [U. S.]

GLYNDON, Baltimore County. 39° 28′, 76° 48′. 700 ft.
A. W. NYCE. Jan., 1893, to Feb., 1895. [Md.]
Record not continuous.

GLYNDON, Baltimore County. 39° 28′, 76° 48′. 700 ft.
J. E. HENRY. March to July, 1895. [Md.]

*GRANTSVILLE, Garrett County. 39° 43′, 79° 10′. 2400 ft.
JACOB S. MILLER. Aug., 1894-99. [Md.] [U. S.]

*GREAT FALLS, Montgomery County. 39° 0′, 77° 15′. 200 ft.
WASHINGTON AQUEDUCT. May, 1877-99. [U. S.] [Md.]
Exp. thermometer and raingauge at 7 a. m. and 2 p. m. Max. and min. thermometers added in Sept., 1897. Special river observations under the direction of the U. S. Weather Bureau.

*GREEN SPRING FURNACE, Washington County. 39° 38′, 77° 55′. 450 ft.
EDWIN G. KINSELL. Jan., 1872, to Nov., 1873; May, 1895-99. [S. I.] [Md.] [U. S.]

HAGERSTOWN, Washington County. 39° 39′, 77° 43′. 550 ft.
REV. JOHN P. CARTER. June, 1852. [S. I.]

HAGERSTOWN, Washington County. 39° 39′, 77° 43′. 560 ft.
CHARLES FELDMAN. Oct., 1889, to March, 1892. [U. S.]
From Oct., 1889, to Nov., 1891, private instruments were used.

*HAGERSTOWN, Washington County. 39° 38′, 77° 43′. 552 ft.
C. L. KEEDY. 1892 to April, 1895; PROF. CHARLES EDWIN CARL, May, 1895-99. [Md.] [U. S.]
In Sept., 1898, max. insolation and min. radiation thermometers were added.

HANCOCK, Washington County. 39° 39′, 78° 12′. 455 ft.
DR. J. S. DIEHL. Jan., 1895, to April, 1896. [Md.]

*HANCOCK, Washington County. 39° 39′, 78° 12′. 455 ft.
J. D. STOTLEMEYER. June, 1898-99. [Md.] [U. S.]

ISTHMUS, Talbot County. 38° 45′, 76° 15′. 20 ft.
ROBERT BANNING. 1843 to 1845.

Observations at sunrise, 9 a. m., 3 p. m. and 9 p. m. Reported to Prof. Espy, U. S. Navy Department, Washington, D. C. Record not continuous.

*JEWELL, Anne Arundel County. 38° 45′, 76° 37′. 165 ft.
JOSEPH PLUMMER. Sept., 1888-99. [Md.] [U. S.]

KENSINGTON, Montgomery County. 39° 2′, 77° 5′. 300 ft.
GILBERT H. HICKS. May to Aug., 1898. [Md.]

KENT ISLAND, Queen Anne's County. 39° 1′, 76° 19′. 10 ft.
P. T. PRICE. March and April, 1898. [Md.]

LAKE SHORE (1), Anne Arundel County. 39° 6′, 76° 26′. 7 ft.
JEFFERSON MONROE COOK. March to June, 1898. [Md.]
Max. insolation and min. terrestrial radiation thermometers.

LAKE SHORE (2), Anne Arundel County. 39° 6′, 76° 27′. 45 ft.
WM. H. CHAIRS. April, 1898. [Md.]
Max. insolation and min. terrestrial radiation thermometers.

LA PLATA, Charles County. 76° 58′, 38° 32′. 190 ft.
J. S. TURNER. July, 1894, to Dec., 1895. [Md.]

*LAUREL, Prince George's County. 39° 6′, 76° 52′. 150 ft.
DR. T. M. BALDWIN. April, 1895-99. [Md.] [U. S.]

LEITERSBURG, Washington County. 39° 42′, 77° 37′. 500 ft.
LEWIS JACOBS BELL. Oct., 1851-52. [S. I.]

LEITERSBURG, Washington County. 39° 42′, 77° 37′. 500 ft.
JACOB EMERICK BELL. June, 1852, to June, 1880. [S. I.]

LEONARDTOWN, St. Mary's County. 38° 18′, 76° 38′. 45 ft.
DR. ALEXANDER MCWILLIAMS. Jan., 1858, to Dec., 1859. [S. I.]
Record not continuous.

LEONARDTOWN, St. Mary's County. 38° 18′, 76° 38′. 50 ft.
GEORGE W. JOY. Nov., 1889, to July, 1893. [U. S.] [Md.]
Record not continuous. Obs. at 7 a. m., 2 p. m., 8 p. m. During 1893 max. and min. thermometers.

LINWOOD, Carroll County. 39° 33′, 77° 10′. 700 ft.
CHARLES F. HANSHEN. May and June, 1871. [S. I.]

LISBON, Howard County. 39° 20′, 77° 4′. 600 ft.
M. W. WARFIELD, JR. Aug. to Dec., 1895. [Md.]
Observations at 8 a. m. and 8 p. m.

*McDonogh, Baltimore County. 39° 24′, 76° 46′. 545 ft.
McDonogh Institute. Jan., 1876-99. [U. S.] [Md.]
No observations during the summer months.

*Mardela Springs (Barron Creek Springs), Wicomico County. 38° 28′, 75° 46′. 25 ft.
Albert E. Ackworth. July, 1888-99. [U. S.] [Md.]

Marshall Hall, Charles County. 38° 41′, 77° 6′. 25 ft.
F. H. Deal. Aug. to Dec., 1894. [Md.]

Mt. Airy, Carroll County. 39° 22′, 77° 5′. 813 ft.
Dr. E. A. Vannort. Jan., 1872, to Nov., 1874. [S. I.]

Mt. St. Mary's, Frederick County. See: Emmitsburg.

Mt. Savage (Eyrie House), Allegany Co. 39° 42′, 78° 52′. 1500 ft.
T. C. Atkinson. Jan. to Dec., 1846. [S. I.]
Temperature only.

*New Market, Frederick County. 39° 23′, 77° 17′. 550 ft.
Dr. Howard Hanford Hopkins. June, 1873, to Oct., 1879; 1885-99. [U. S.] [Md.]
Barometric readings from 1873-79.

New Midway, Frederick County. 39° 34′, 77° 17′. 500 ft.
George F. Smith. Sept., 1886, to Feb., 1888. [U. S.]

New Windsor, Carroll County. 39° 31′, 77° 6′. 700 ft.
Professor J. P. Nelson, Calvert College. Jan. to Dec., 1852. [S. I.]
Record not continuous.

Nottingham, Prince George's County. 38° 42′, 76° 43′. 25 ft.
Dr. Richard Brooke, Brookfield. Sept., 1753, to Dec., 1757.
Daily a. m. and p. m. readings of the thermometer, with character of the day and direction of the wind. Complete record for the first year, and max. and min. temperature for each month thereafter, published in the Philosophical Transactions of London, for 1759.

Nottingham, Prince George's County. 38° 42′, 76° 43′. 25 ft.
A. P. Dalrymple. Feb. and March, 1849. [S. I.]

Oakland, Garrett County. 39° 25′, 79° 25′. 2400 ft.
L. R. Cafran. Dec., 1857, to June, 1858. [S. I.]
Temperature only.

Oakland, Garrett County. 39° 25′, 79° 25′. 2400 ft.
J. D. Hamill. Jan. and Feb., 1893. [Md.]
Temperature only.

OAKLAND, Garrett County. 39° 25', 79° 25'. 2400 ft.
DR. J. LEE MCCOMAS. April, 1893, to March, 1896. [Md.]

OAKLAND, Garrett County. 39° 25', 79° 25'. 2400 ft.
E. E. SOLLARS. June to Aug., 1898. Rainfall only.
Reports sent to Division of Soils, U. S. Department of Agriculture.

OAKLAND MILLS, Howard County. 39° 13', 76° 51'. 300 ft.
P. TABB. Oct. to Dec., 1864. [S. I.]

OCEAN CITY, Worcester County. 38° 18', 75° 5'. 10 ft.
U. S. WEATHER BUREAU. Aug., 1882, to May, 1887. [U. S.]
Exp., max. and min. thermometers and raingauge.

*OCEAN CITY, Worcester County. 38° 18', 75° 5'. 10 ft.
EDWARD MARSHALL SCOTT. March to May, 1898; Dec., 1898-99.
[Md.] [U. S.]

OLDTOWN, Allegany County. 39° 32', 78° 37'. 700 ft.
DR. H. C. SHIPLEY. May to Aug., 1895. [Md.]

*POCOMOKE CITY, Worcester County. 38° 5', 75° 34'. 37 ft.
RILEY MARTIN STEVENSON. March, 1894-99. [Md.] [U. S.]

POPE'S CREEK, Charles County. 38° 24', 77° 0'. 20 ft.
GEORGE DENT. July, 1894, to Aug., 1895. [Md.]

PORT DEPOSIT, Cecil County. 39° 36', 76° 8'. 25 ft.
HENRY W. THORPE. June and July, 1850. [S. I.]

*PORT DEPOSIT, Cecil County. 39° 36', 76° 8'. 25 ft.
TOME INSTITUTE. April, 1897-99. [Md.] [U. S.]
PROF. A. H. LAMB, April to July, 1897; J. I. FRANCE, Aug., 1897-99.

PRINCESS ANNE, Somerset County. 38° 13', 75° 42'. 25 ft.
DR. SAMUEL KER. 1823 to 1847.
Temperature and rainfall. Some of the results published currently in the Somerset Herald.

*PRINCESS ANNE, Somerset County. 38° 13', 75° 42'. 20 ft.
JAMES ROBERTSON STEWART. 1888 to Oct., 1889; July, 1894-99.
[U. S.] [Md.]

*QUEENSTOWN, Queen Anne's County. 39° 0', 76° 9'. 10 ft.
DR. WILLIAM KENNEDY CARROLL. 1879 to Dec., 1881; March, 1898-99.
[U. S.] [Md.]
Max. insolation and min. terrestrial radiation thermometers since March, 1898.

REISTERSTOWN, Baltimore County. 39° 28′, 76° 50′. 750 ft.
REV. R. HEBER MURPHEY. Nov., 1872, to Feb., 1875. [S. I.] [U. S.]

RIDGE, St. Mary's County. 38° 7′, 76° 22′. 50 ft.
T. G. STAGG. May, 1856, to June, 1857. [S. I.]

*ROCK HALL (1), Kent County. 39° 8′, 76° 15′. 20 ft.
CHARLES NATHAN SATTERFIELD. March, 1898-99. [Md.]

*ROCK HALL (2), Kent County. 39° 8′, 76° 13′. 25 ft.
ISAAC LASSELL LEARY. Feb., 1898-99. [Md.]
Max. insolation and min. terrestrial radiation thermometers during April and May, 1898.

ST. CHARLES COLLEGE, see: Ellicott City.

ST. INIGOES, St. Mary's County. 38° 9′, 76° 23′. 10 ft.
JAMES F. ELLICOTT. Sept., 1871, to Feb., 1879. [S. I.] [U. S.]

ST. MARY'S CITY, St. Mary's County. 38° 11′, 76° 26′. 45 ft.
REV. JAMES STEPHENSON. Dec., 1859; Jan., 1861, to Feb., 1870; Feb., 1871. [S. I.]
Record not continuous.

SALISBURY, Wicomico County. 38° 22′, 75° 35′. 30 ft.
COL. LEMUEL MALONE, Jan. to Oct., 1893; DR. L. S. BELL, Nov., 1893-95. [Md.]
Record incomplete. Exposed thermometer only to Aug., 1894.

SAM'S CREEK, Carroll County. 39° 30′, 77° 3′. 750 ft.
FRANCIS J. DE VILLISS. June, 1871, to Aug., 1874. [S. I.]
Record not continuous.

*SANDY POINT, Worcester County. 38° 14′, 75° 12′. 12 ft.
JAMES B. DIRICKSON. April, 1898-99. [Md.]
Max. insolation and min. terrestrial radiation thermometers.

SANDY SPRING, Montgomery County. 39° 9′, 77° 0′. 500 ft.
ISAAC BOND. 1850 to 1851 (7 months). [S. I.]

SANDY SPRING, The Cedars, Montgomery Co. 39° 9′, 77° 1′. 500 ft.
ALLAN FARQUHAR. Dec., 1876, to June, 1884. [U. S.]
Barometric observations.

SANDY SPRING, Montgomery County. 39° 9′, 77° 1′. 500 ft.
H. H. MILLER. June, July and September, 1898.
Rainfall only. Reports sent to the Division of Soils, U. S. Department of Agriculture.

*SHARPSBURG, Washington County. 39° 27′, 77° 44′. 420 ft.
ROBERT LEE HIBERGER. Nov., 1894-99. [Md.] [U. S.]

SCHELLMAN HALL, see: Sykesville.

*SMITHSBURG, Washington County. 39° 39′, 77° 33′. 650 ft.
ALBERT F. DIFFENDAL. 1879-99.
From 1879 to 1892 thermometer read at 7 a. m. Self-registering thermometers since June, 1892. Raingauge since July 1, 1891. Mercurial barometer since Nov. 5, 1895. Private instruments and records.

SMITHSBURG, Washington County. 39° 39′, 77° 34′. 750 ft.
REV. LEWIS JACOBS BELL. April to Dec., 1897. [Md.]

*SMITHSBURG (1), Washington County. 39° 39′, 77° 35′. 750 ft.
JOSEPH L. MILLER. Feb., 1898-99. [Md.]
Max. insolation and min. terrestrial radiation since April, 1898.

*SMITHSBURG (2), Washington County. 39° 39′, 77° 33′. 900 ft.
DR. D. W. CROWTHER. Feb., 1898-99. [Md.]
Max. insolation and min. terrestrial radiation thermometers since May, 1898.

SNOW HILL, Worcester County. 38° 10′, 75° 25′. 15 ft.
Occasional reports sent to the Franklin Institute in 1838 and 1839.

*SOLOMON'S, Calvert County. 38° 19′, 76° 27′. 20 ft.
DR. WILLIAM HENRY MARSH. Jan., 1892-99. [Md.] [U. S.]

SPENCERVILLE, Montgomery County. 39° 7′, 76° 58′. 525 ft.
CALEB STABLER. May to Dec., 1898. [Md.]
Rainfall only.

*SUDLERSVILLE, Queen Anne's County. 39° 11′, 75° 50′. 65 ft.
J. S. BARWICK. Oct., 1898-99. [U. S.] [Md.]

*SUNNYSIDE, Garrett County. 39° 20′, 79° 27′. 2500 ft.
JOHN GEORGE KNAUER. Jan., 1893-99. [Md.] [U. S.]
Jan. 1, 1893, to July 1, 1896, thermometer read at 7 a. m., 2 p. m. and 9 p. m. In 1895 raingauge added. Since July, 1896, max. and min. thermometers.

SYKESVILLE, Shellman Hall, Carroll County. 39° 23′, 76° 58′. 600 ft.
DR. WILLIAM BAER and MISS HARRIET M. BAER. Jan., 1846, to Dec., 1865. [S. I.]
Temperature 1846-65; rainfall 1849-65.

TANEYTOWN, Carroll County. 39° 40′, 77° 10′. 500 ft.
DAVID BOWERS. Oct. to Dec., 1893. [Md.]
Rainfall only.

TANEYTOWN, Carroll County. 39° 40′, 77° 9′. 500 ft.
DR. C. W. WEAVER. 1891 to May, 1893. [Md.]
Rainfall only.

*TANEYTOWN, Carroll County. 39° 40′, 77° 11′. 490 ft.
PROFESSOR HENRY MEIER, Milton Academy. July, 1896-99. [Md.] [U. S.]

UNION BRIDGE, Carroll County. 39° 34′, 76° 10′. 400 ft.
W. GILLINGHAM. May, 1864. [S. I.]

UPPER MARLBORO, Prince George's County. 38° 48′, 76° 45′. 50 ft.
J. BENSON PERRIE. May, 1893, to Feb., 1896. [Md.]

*VAN BIBBER, Harford County. 39° 26′, 76° 18′. 22 ft.
H. A. WROTH. Oct., 1895-99. [Md.] [U. S.]

*WESTMINSTER, Carroll County. 39° 35′, 77° 0′. 700 ft.
WILLIAM H. and CHAS. H. VANDERFORD. Jan., 1880-99.
Thermometer read at 7 a. m., and 2 p. m. Private instrument and record.

*WESTMINSTER, Carroll County. 39° 35′, 76° 59′. 720 ft.
WESTERN MARYLAND COLLEGE. Jan. to March, 1893; Jan., 1895-99 JOHN T. CASSELL, Jan. to March, 1893; PROF. ROWLAND WATTS, Jan., 1895, to Aug., 1898; DR. CLEVELAND ABBE, JR., Sept., 1898-99. [Md.] [U. S.]
No observations made during the college summer vacations.

*WESTERNPORT, Allegany County. 39° 28′, 79° 2′. 1000 ft.
PROFESSOR OLIVER H. BRUCE. Nov., 1894-99. [Md.] [U. S.]

WINCHESTER, Worcester County. 38° 22′, 75° 8′. 5 ft.
WILLIAM A. DISHAROON. March to June, 1898. [Md.]

WOODLAWN, Cecil County. 39° 38′, 76° 4′. 465 ft.
JAMES O. MCCORMICK. Jan., 1865, to Dec., 1875. [S. I.] [U. S.]
Barometric observations.

WOODSTOCK, Howard County. 39° 20′, 76° 52′. 392 ft.
WOODSTOCK COLLEGE, Baltimore Co. Dec., 1870-99. Observers: REV. J. M. DEGNI (S. J.), 1870-73, 1880-88; REV. A. X. VALENTE (S. J.), 1874-79; REV. SAMUEL FRISBEE (S. J.), Aug., 1888-89; REV. T. O'SULLIVAN (S. J.), 1890; REV. T. J. A. FREEMAN (S. J.), 1891-99. [S. I.] [U. S.] [Md.]
Private instruments. Barometric observations since 1874.

WYE ISLAND, Queen Anne's County. 38° 53′, 76° 10′. 15 ft.
ANNIE MCCLYMENT. June to Aug., 1898.
Rainfall only. Record sent to the Division of Soils, U. S. Department of Agriculture.

DELAWARE.

CAPE HENLOPEN, Sussex County. 38° 48′, 75° 5′. 25 ft.
U. S. SIGNAL SERVICE (Weather Bureau). June, 1885, to June, 1887. [U. S.]
Temperature, rainfall and wind direction.

DELAWARE BREAKWATER, Sussex County. 38° 48′, 75° 10′. 20 ft.
U. S. SIGNAL SERVICE (Weather Bureau). Feb., 1880, to Feb., 1885. [U. S.]
Pressure, temperature, rainfall, wind direction and velocity.

DELAWARE CITY (Fort Delaware), New Castle Co. 39°35′,75°34′. 10 ft.
ASSISTANT SURGEONS, U. S. Army. Jan., 1825-59; Jan., 1862-Sept., 1870. [S. G. O.]
Record not continuous; about 20 years of observations.

DELAWARE CITY, New Castle County. 39° 35′, 75° 35′. 10 ft.
J. M. VANHELKE (?). March, 1866, to March, 1867; Jan., 1874, to Nov., 1876. [S. I.]
Record not continuous.

*DOVER, Kent County. 39° 10′, 75° 30′. 44 ft.
JOHN H. BATEMAN. July, 1870-99. [S. I.] [U. S.] [Del.] [Md.]

DOVER, Kent County. 39° 10′, 75° 30′. 40 ft.
JNO. S. JESTER. Oct., 1891 to Dec., 1896. [Md.]

GEORGETOWN, Sussex County. 38° 43′, 75° 22′. 50 ft.
DR. D. W. MAULD. July, 1857, to Dec., 1859. [S. I.]

*KIRKWOOD, New Castle County. 39° 35′, 75° 41′. 70 ft.
W. C. L. CARNAGY. 1883-99.
Temperature observations only. Private instrument.

*MIDDLETOWN, New Castle County. 39° 26′, 75° 44′. 65 ft.
GEORGE W. ERNST. June, 1889, to Nov., 1890; MRS. GEO. W. ERNST. Nov., 1890-99. [Del.]

MILFORD, Kent County. 38° 55′, 75° 25′. 20 ft.
RICHARD A. MARTIN, W. R. PHILLIPS, A. C. WHITTIER, R. A. GILMAN. Dec., 1857, to Dec., 1874. [S. I.]
Record much broken.

*MILFORD, Kent County. 38° 55′, 75° 25′. 20 ft.
JACOB Y. FOULK. Jan., 1874-99. [U. S.] [Del.] [Md.]

*MILLSBORO, Sussex County. 38° 40′, 75° 20′. 20 ft.
REV. LEWIS WHEELER WELLS. March, 1890-99. [Del.] [Md.] [U. S.]

NEWARK, New Castle County. 39° 38′, 75° 47′. 120 ft.

DELAWARE COLLEGE. E. E. NORTON, CRAWFORD and others. 1847; 1854-58. [S. I.]

Record not continuous.

*NEWARK, New Castle County. 39° 40′, 75° 45′. 136 ft.

DELAWARE COLLEGE. PROF. GEORGE A. HARTER, Sept., 1888-91; PROF. WILLIAM HERBERT BISHOP, Aug., 1891-99. [Del.] [Md.] [U. S.]

Barometer and Draper's self-recording thermometer.

*SEAFORD, Sussex County. 38° 39′, 75° 36′. 40 ft.

ROBERT W. FISHER, June to Oct., 1889; F. D. JAMES, Oct. to Dec., 1889; H. L. WALLACE, Jan., 1890, to Sept., 1897; WALTER F. WALLACE, Oct., 1897-99. [Del.] [Md.] [U. S.]

Barometric observations since June, 1890.

VIOLA, Kent County. 39° 2′, 75° 32′. 65 ft.

J. A. FARLOW. Nov. and Dec., 1888. [U. S.]

Temperature and rainfall at 7 a. m. and 7 p. m.

WILMINGTON, New Castle County, Del. 39° 44′, 75° 33′. 25 ft.

REV. JOHN CAMPANIUS. 1644 and 1645.

Rev. Campanius, of the Swedish Colony, kept a daily journal of the state of the weather during 1644 and 1645. Some extracts from this record may be found in Rev. Campanius Holm's "Kort Beskrifning om Nya Sverige," 4°, Stockholm, 1702; also in Trans. Amer. Phil. Soc., Phila., vol. i, 1818, pp. 340-352. This is probably the first systematic record of the weather in America. The place of observation was near Wilmington.

WILMINGTON, New Castle County. 39° 44′, 75° 33′. 25 ft.

DR. HENRY GIBBONS. Aug., 1834, to July, 1835.

Record of temperature; reports sent to the Franklin Institute, Philadelphia.

WILMINGTON, New Castle County. 39° 44′, 75° 33′. 115 ft.

DR. U. D. HEDGES. Jan., 1864, to Oct., 1865. [S. I.]

WILMINGTON, New Castle County. 39° 44′, 75° 33′. 115 ft.

F. C. D. MCKAY. April, 1894, to Nov., 1896. [Md.]

Exposed and wet-bulb thermometer at 7 a. m., 2 p. m. and 9 p. m., and raingauge; max. and min. thermometers.

DISTRICT OF COLUMBIA.[1]

WASHINGTON CITY. 38° 53′, 77° 2′. 30 ft.

HON. JOHN QUINCY ADAMS and GEN. JOSIAH MEIGS. Jan., 1820, to Dec., 1821.

Temperature only.

WASHINGTON CITY. 38° 54′, 77° 2′. 30 ft.

JULES DE WALLENSTEIN. 1822-24.

Four observations of temperature daily. Results published in the Trans. Amer. Phil. Soc., Phila., vol. ii, 1825.

WASHINGTON CITY. 38° 54′, 77° 2′. 30 ft.

ASS'T SURGEON R. LITTLE, U. S. Army. Jan., 1823, to Dec., 1834. [S. G. O.]

WASHINGTON CITY.

JUDGE W. C. CRANCH. 1823-39.

WASHINGTON, D. C. (Mt. Pleasant). 38° 55′, 77° 2′. 110 ft.

——— Jan., 1828, to Dec., 1829.

Max. and min. temperatures. From J. Elliot's Historical sketches of the 10 miles square.

WASHINGTON CITY, Capitol Hill. 38° 53′, 77° 1′. 90 ft.

LIEUT. J. M. GILLISS, U. S. Navy. July, 1838, to June, 1842.

Observations published in Sen. Doc. vol. x, 1845, 28th Congress, 2nd session.

*WASHINGTON CITY. 38° 54′, 77° 3′. 112 ft.

U. S. WEATHER BUREAU. Nov., 1870-99. [U. S.]

First order station. Self-recording meteorological instruments.

*WASHINGTON CITY. 38° 54′, 77° 3′. 100 ft.

U. S. NAVAL OBSERVATORY. Jan., 1846-99.

Observations for most of this period published in the annual: "Observations" of the Naval Observatory.

*WASHINGTON, D. C. (Georgetown). 38° 55′, 77° 4′. 150 ft.

CHARLES H. TRUNNELL. 1848 to 1899.

A continuous record of the general character of the day. Occurrences of rain and snow, thunderstorms, and unusual features of the weather. No instrumental records.

WASHINGTON CITY. 38° 53′, 77° 2′. 40 ft.

SMITHSONIAN INSTITUTION. 1850 to 1876. [S. I.]

Observers: H. DIEBITSCH, W. Q. FORCE, H. M. BANNISTER, and others.

WASHINGTON, D. C. (Georgetown). 38° 55′, 77° 5′. 200 ft.

REV. C. B. MACKEE. Dec., 1859, to Feb., 1863. [S. I.]

WASHINGTON, D. C. 38° 54′, 77° 0′. 90 ft.

NATIONAL DEAF MUTE COLLEGE, Kendall Green. June, 1878, to March, 1880. [U. S.]

Record not continuous.

WASHINGTON, D. C.

ROCK CREEK BRIDGE. May, 1877, to Feb., 1889. [U. S.]
Temperature only.

ANACOSTIA, D. C. 38° 57′, 76° 56′. 275 ft.

J. WIESSNER. Sept., 1857, to Aug., 1858. [S. I.]

*DISTRIBUTING RESERVOIR, D. C. 38° 55′, 77° 5′. 150 ft.

OFFICE OF WASHINGTON AQUEDUCT. May, 1877-99. [U. S.] [Md.]
Observations at 7 a. m. and 2 p. m.

*RECEIVING RESERVOIR, D. C. 38° 57′, 77° 7′. 200 ft.

OFFICE OF WASHINGTON AQUEDUCT. May, 1877-99. [U. S.] [Md.]
Observations at 7 a. m. and 2 p. m.

STATIONS DISPLAYING DAILY WEATHER-FORECAST FLAGS.

MARYLAND.

STATION.	DISPLAYMAN.	PERIOD.
Annapolis.*	W. M. Abbott.	1891–1899.
Appleton.	W. C. Henderson.	1893–1894.
Baltimore.*	U. S. Weather Bureau.	1891–1899.
	The Anchorage.	1894–1899.
	Baltimore and Lehigh R. R. Co.	1894–1899.
	Western Md. R. R.	1896–1899.
	Maryland Steel Co. Sparrows Point Whistle Signals.	1892–1894.
Barron Creek Springs.	See: Mardela Springs.	
Bel Air.	N. N. Nock.	1891–1894.
Berlin.	L. L. Dirickson, Jr.	1896–1899.
Boonsboro.	C. E. Huntzbery.	1896–1899.
Bradshaw.	B. F. Taylor.	1891–1899.
Buckeystown.	A. W. Nicodemus.	1892–1894.
Cambridge.	Calvert Orem.	1893–1894.
	Samuel Lehman.	1894–1899.
Chestertown.	J. S. Vandegrift.	1893.
	Charles S. Smith.	1896–1899.
Darlington.	A. F. Galbreath.	1891–1893.
Dickerson.	W. H. Dickerson.	1891–1894.
Easton.	G. W. Minnick.	1892–1894.
	Dr. Thomas A. Councell.	1898–1899.
Emmitsburg.	Prof. J. A. Mitchell.	1891–1892, 1896–1899.
	Jos. H. Martin.	1893–1895.
Flintstone.	N. T. Downs.	1895.

* Storm-signal display stations.

Station.	Displayman.	Period.
Frederick.	The News.	1893–1897.
	G. S. DeGrange.	1898–1899.
Frostburg.	C. J. Conner.	1891–1893.
	J. N. Benson.	1894–1897.
	Jno. Davis.	1898–1899.
Garey.	Walter Dorsey.	1894–1895.
Glyndon.	A. W. Nyce.	1893–1894.
	John Dyer.	1894.
Grantsville.	A. L. Gnagey.	1892.
	T. H. Bittinger.	1893–1894.
Greensboro.	Plummer and Plummer.	1891–1893.
Hagerstown.	R. J. Hamilton.	1891–1893.
	J. P. Harter.	1894–1895.
	Ira W. Hays.	1896–1899.
Hampstead.	H. H. Meals.	1894–1895.
Hancock.	T. Lee Carl.	1891.
Havre de Grace.	W. S. McCombs.	1891–1894.
Hyattsville.	E. B. Rowell.	1893.
La Plata.	J. S. Turner.	1894–1895.
Lonaconing.	J. J. Robinson.	1891–1894.
Manchester.	C. J. H. Ganter.	1896–1899.
Mardela Springs.	L. A. Wilson.	1893–1894.
Middletown.	G. C. Rhoderick, Jr.	1891–1899.
Oakland.	J. M. Litzinger.	1891–1893.
	H. J. Mayer.	1895.
	Dr. J. Lee McComas.	1893–1899.
Ocean City.	Capt. J. J. Demton.	1897–1899.
Odenton.	C. W. Claggett.	1891–1892.
	E. B. Watts.	1893–1894.
Oxford.*	H. S. Matthews.	1896–1899.
Pocomoke City.	R. M. Stevenson.	1894–1899.
Princess Anne.	L. F. Wilson.	1894–1895.
Ridgely.	J. A. Sigler.	1892–1893.
Rising Sun.	E. A. Reynolds.	1893–1895.
	Dr. R. L. Kirk.	1895.
Rockville.	Emmitt Dove.	1893–1894.
	Virgil T. Poole.	1895.
Salisbury.	L. W. Gunby.	1891–1895.
	W. Benjamin.	1895.
	Miss M. D. Ellegood.	1896–1898.
	Baltimore, Chesapeake and Atlantic R. R.	1896–1899.
	E. J. Adkins.	1899.
Snow Hill.	Purnell and Vincent.	1891–1899.
St. Michael's.	E. M. Jefferson.	1891–1893.
Sykesville.	James S. Hyatt.	1894–1897.
	A. Hepner.	1898–1899.
Taneytown.	Dr. C. W. Weaver.	1891–1893.
	Prof. H. Meier.	1898–1899.

Station.	Displayman.	Period.
West Friendship.	Thomas Hanson.	1894–1895.
Westminster.	W. S. Myer and Bro.	1891–1893.
	N. I. Gorsuch and Son.	1898–1899.
Westover.	E. D. Long.	1898–1899.
Woodsboro.	G. F. Smith.	1893–1894.
Washington, D. C.	U. S. Weather Bureau.	1891–1899.

DELAWARE.

Station.	Displayman.	Period.
Bridgeville.	T. J. Gray.	1892–1893.
Delaware City.	W. E. Reybold.	1892–1894.
Dover.	Philip Burnet.	1893–1895.
Felton.	J. H. Hubbard. Whistle signals.	1892–1893.
Fredonia.	Miss L. T. Frazier.	1894–1895.
	Miss E. V. Newnom.	1894–1895.
Hartley.	Miss C. A. Forde.	1894–1895.
Kenton.	W. S. Arthurs.	1894–1895.
Laurel.	E. D. C. Hegeman.	1894.
	"The Sussex Countian."	1896–1899.
Milford.	J. Y. Foulk.	1891–1899.
Seaford.	Dr. Hugh Martin.	1891–1893.
	H. L. Wallace.	1892–1897.
	W. T. Wallace.	1898–1899.
Smyrna.	A. D. Yocum.	1894.
	A. E. Jardine.	1896–1899.
Wilmington.	Wm. Lawton.	1891–1895.
	Chief Operator Wilmington & Northern R. R.	1896–1899.

Stations Having Records of 10 Years or More, with the Periods of Observation.

MARYLAND.

Annapolis.	35 years.	1822, 1831–1834, 1843–1845, 1855–1859, 1861–1876, 1894–1899.
Baltimore.	75 years.	1817–1824, 1829, 1831–1859, 1861–1862, 1864–1899.
Bladensburg.	12 years.	1854–1865.
Chestertown.	30 years.	1855–1864, 1880–1899.
College Park.	13 years.	1861–1862, 1888–1899.
Cumberland.	40 years.	1859–1899.
Emmitsburg.	32 years.	1866–1873, 1875–1899.
Fallston.	28 years.	1870–1899.
Fort Washington.	20 years.	1824–1835, 1851–1853, 1868–1872.

Frederick.	77 years.	1821–1899.
Great Falls.	22 years.	1877–1899.
Jewell.	11 years.	1888–1899.
Leitersburg.	30 years.	1851–1880.
McDonogh.	23 years.	1876–1899.
Mardela Springs (Barron Creek)	11 years.	1888–1899.
New Market.	21 years.	1873–1879, 1885–1899.
Princess Anne.	32 years.	1823–1847, 1888–1889, 1894–1899.
Smithsburg.	20 years.	1879–1899.
St. Mary's City.	10 years.	1861–1871.
Sykesville.	20 years.	1846–1865.
Westminster.	19 years.	1880–1899.
Woodlawn.	11 years.	1865–1875.
Woodstock.	28 years.	1870–1899.

DELAWARE.

Dover.	29 years.	1870–1899.
Fort Delaware.	48 years.	1825–1859, 1862–1870.
Middletown.	10 years.	1889–1899.
Milford.	35 years.	1857–1858, 186(?)–1874, 1874–1899.
Newark.	17 years.	1847, 1854–1858, 1888–1899.
Seaford.	10 years.	1889–1899.

DISTRICT OF COLUMBIA.

Distributing Reservoir.	22 years.	1877–1899.
Receiving Reservoir.	22 years.	1877–1899.
Washington.	76 years.	1820–1842, 1846–1899.

STATIONS AT AN ELEVATION OF 1000 FEET OR MORE ABOVE SEA-LEVEL.

Blue Mountain House, Washington Co., 1200 feet.
Deer Park, Garrett Co., 2500 feet.
Frostburg, Allegany Co., 2100 feet.
Grantsville, Garrett Co., 2400 feet.
Mt. Savage, Allegany Co., 1500 feet.
Oakland, Garrett Co., 2400 feet.
Sunnyside, Garrett Co., 2500 feet.
Westernport, Allegany Co., 1000 feet.

List of Observers with Period of Observation.

MARYLAND.

Name.	Period.	Place.
Abbe, Dr. Cleveland, Jr.	1898–1899.	Westminster.
Abbott, J. E.	1894–1899.	Annapolis.

Name.	Period.	Place.
Acworth, Albert E.	1888–1899.	Mardela Springs
Apple, President	——	Frederick.
Atkinson, T. C.	1846.	Mt. Savage.
Baer, Dr. William. / Baer, Miss Harriet M.	1846–1865.	Sykesville.
Baer, Miss Harriet M.	1866.	Frederick.
Baldwin, Dr. T. M.	1895–1899.	Laurel.
Banning, Robert	1843–1845.	Isthmus.
Bantz, G. E.	——	Frederick.
Bardeen, Prof. F. L.	1880–1895.	Chestertown.
Barkman, Justin	1896–1898.	Flintstone.
Barwick, J. S.	1898–1899.	Sudlersville.
Bell, Jacob Emerick	1852–1880.	Leitersburg.
Bell, Rev. Lewis Jacobs	1851–1852. 1897.	Leitersburg. Smithsburg.
Bell, Dr. L. S.	1893.	Salisbury.
Bell, R. J.	1876–1877.	Baltimore.
Berry, Thomas	1893–1894.	Benedict.
Black, William	1879.	Baltimore.
Boies, A. H.	1881–1882.	Federalsburg.
Bond, Isaac	1850–1851.	Sandy Spring.
Boyd, W. T.	1874–1875.	Baltimore.
Bowers, David	1893.	Taneytown.
Brantz, Capt. Lewis	1817–1824, 1829, 1836–1837.	Baltimore.
Brooke, Dr. Richard	1753–1757.	Nottingham.
Bruce, Prof. Oliver H.	1894–1899.	Westernport.
Bruce, Webster	1896–1897.	Cumberland.
Brown, Francis Frederick	1891–1899.	Boettcherville.
Browning, Robert E.	1898.	College Park.
Cafran, L. R.	1857–1858.	Oakland.
Carl, Prof. Charles Edwin	1893–1899.	Hagerstown.
Carmody, T.	——	Emmitsburg.
Carroll, Dr. William Kennedy	1879–1881, 1898–1899.	Queenstown.
Carter, Rev. John P.	1852.	Hagerstown.
Cassell, John T.	1893.	Westminster.
Chapuis, Rev. H. M., S. S.	1895–1897.	Ellicott City.
Charlotte Hall School.	1892–1899.	Charlotte Hall.
Coad, Col. J. Edwin	1893–1898.	Valley Lee.
Coad, Prof. J. Francis	1893–1899.	Charlotte Hall.
Cook, Jefferson Monroe	1898.	Lake Shore.
Cowan, James E.	1871.	Baltimore.
Corey, Edward E.	1898.	Betterton.
Cox, Walter	1894–1895.	Bel Alton.
Cronk, C. P.	1888–1895.	Baltimore.
Crouch, John Wilson	1898–1899.	Chase.
Crowther, Dr. D. W.	1898–1899.	Smithsburg.
Curtiss, Prof. G. G.	1870–1894.	Fallston.

NAME.	PERIOD.	PLACE.
Curtiss, J. H.	1894–1899.	Fallston.
Dalrymple, A. P.	1849.	Nottingham.
Deal, F. H.	1894.	Marshall Hall.
Degni, Rev. J. M., S. J.	1870–1873.	Woodstock.
Dent, George	1894–1895.	Pope's Creek.
De Sellum, John T.	1871, 1888–1891.	Gaithersburg.
DeVilliss, Francis J.	1871–1874.	Sam's Creek.
Diehl, Dr. J. S.	1895–1896.	Hancock.
Diffendal, Albert F.	1879–1899.	Smithsburg.
Dirickson, Dr. J. E.	1898.	Berlin.
Dirickson, James B.	1898–1899.	Sandy Point.
Dorley, A. F.	——	Emmitsburg.
Downs, Newton T.	1896.	Flintstone.
Dutton, Prof. J. R.	1855–1864.	Chestertown.
Duval, M.	——	Annapolis.
Edelen, B. M., Jr.	1892.	Bryantown.
Edmondson, Dr. T., Jr.	1835–1837, 1846–1853.	Baltimore.
Elder, Prof.	1838–1839.	Emmitsburg.
Ellicott, James F.	1871–1879.	St. Inigoes.
Evans, William H.	1898.	Chase.
Fallston School.	1870–1899.	Fallston.
Farquhar, Allan	1876–1884.	Sandy Spring.
Feldman, Charles	1889–1892.	Hagerstown.
Feldman, Charles	1892–1893.	Edgemont.
Felger, George W.	1882–1888.	Baltimore.
Fenby, William	1893–1894.	Fenby.
Finch, F.	1844.	Elkton.
Ford, Samuel Lafayette	1898–1899.	Boonsboro.
Fort Foote.	1871–1878.	Prince George's Co.
Fort McHenry.	1831–1859, 1861–1862, 1864–1892.	Baltimore.
Fort Severn.	1822, 1831–1834, 1843–1845.	Annapolis.
Fort Washington.	1824–1835, 1851–1853, 1868–1872.	Prince George's Co.
France, J. I.	1897–1899.	Port Deposit.
Frantz, William Wallace	1898–1899.	Clear Spring.
Freeman, Rev. T. J. A., S. J.	1891–1899.	Woodstock.
Frisbee, Rev. Samuel, S. J.	1888–1889.	Woodstock.
Galbreath, Prof. A. F.	1891–1899.	Darlington.
Gillingham, W.	1864.	Union Bridge.
Giraud, Prof.	1843.	Emmitsburg.
Goodman, W. R.	——	Annapolis.
Gorgas, A. C.	——	Annapolis.
Grape, G. S.	1865.	Catonsville.
Hamill, J. D.	1893.	Oakland.
Hanshen, Charles F.	1871.	Linwood.
Harig, Rev. George Lewis, S. S.	1897–1899.	Ellicott City.
Harris, James Sheppard	1898–1899.	Coleman.
Harrison, George W.	1880.	Deer Park.

NAME.	PERIOD.	PLACE.
Henry, J. E.	1895.	Glyndon.
Henshaw, H. E.	1861–1863, 1871–1872.	Frederick.
Henshaw, J. K.	1869–1870.	Frederick.
Hiberger, Robert Lee	1894–1899.	Sharpsburg.
Hodson, T. Sherwood	——	Crisfield.
Hoover, F. G.	1843.	Emmitsburg.
Hopkins, Dr. Howard Hanford	1873–1879, 1885–1899.	New Market.
Humphrey, Pres. H.	1838.	Annapolis.
Hunt, George E.	1896–1897.	Baltimore.
Huntzbery, Charles E.	1898–1899.	Boonsboro.
Johns Hopkins Hospital.	1894–1899.	Baltimore.
Johnson, John A.	1878–1879, 1881.	Glyndon.
Jones, Dr. C. M.	1861–1862.	College Park.
Jourdan, Prof. Charles H.	1867–1872.	Emmitsburg.
Joy, George W.	1889–1893.	Leonardtown.
Kabernagle, John	1875.	Baltimore.
Ker, Dr. Samuel	1823–1847.	Princess Anne.
Kinsell, Edwin G.	1872–1873, 1895–1899.	Green Spring Furnace.
Koehler, Henry	1858–1859.	Frederick.
Knauer, John George	1893–1899.	Sunnyside.
Lamb, Prof. A. H.	1897.	Port Deposit.
Lantz, W. A.	——	Frederick.
Leary, Isaac Lassell	1898–1899.	Rock Hall.
Loose, W. E., Jr.	1898.	Clear Spring.
Lowndes, Benjamin O.	1854–1865.	Bladensburg.
Malone, Col. Lemuel	1893.	Salisbury.
Marbury, J. B.	1895–1896.	Baltimore.
Marsh, Dr. William Henry	1892–1899.	Solomon's.
Mayer, Prof. Alfred M.	1857–1859.	Baltimore.
McComas, Dr. J. Lee	1893–1896.	Oakland.
McCormick, James O.	1865–1875.	Woodlawn.
McDonogh Institute.	1876–1899.	McDonogh.
McGann, E. W.	1877–1879.	Baltimore.
McWilliams, Dr. Alexander	1858–1859.	Leonardtown.
Meier, Prof. Henry	1896–1899.	Taneytown.
Miller, Joseph L.	1898–1899.	Smithsburg.
Miller, Jacob S.	1894–1899.	Grantsville.
Milton Academy.	1896–1899.	Taneytown.
Minnick, Geo. W. Minnick, S. P.	1891–1895.	Easton.
Mitchell, Dr. James A.	1888–1899.	Emmitsburg.
Mogue, James E.	1888–1890.	Gambrill's.
Morris, Capt. Jacob G.	1867–1899.	Easton.
Mt. St. Mary's College.	1838–1839, 1843, 1867–1873, 1875–1899.	Emmitsburg.
Murphey, John J.	1879.	Baltimore.
Murphey, Rev. R. Heber	1872–1875.	Reisterstown.
Myers, John Miller	1893–1899.	Bachman's Valley.

NAME.	PERIOD.	PLACE.
Nelson, Prof. J. P.	1852.	New Windsor.
Nyce, A. W.	1895.	Glyndon and Garrison
Orem, Calvert	1898.	Cambridge.
O'Sullivan, Rev. D. T., S. J.	1890.	Woodstock.
Oswald, E. Ingram	1888–1899.	Chewsville.
Parr, Henry	1888–1890.	Galena.
Patterson, Prof. Harry Jacob	1888–1899.	College Park.
Patterson, T. L.	1840.	Cumberland.
Penrod, Hiram	1871–1874.	Baltimore.
Perrie, J. Benson.	1893–1896.	Upper Marlboro.
Poole, Virgil T.	1894–1895.	Rockville.
Plummer, Joseph	1888–1899.	Jewell.
Price, P. T.	1898.	Kent Island.
Quynn, Caspar	1875–1899.	Frederick.
Ramsdell, F. C.	1891–1899.	Denton.
Reudter, Augustus	——	Emmitsburg.
Sahm, Jacob	1836–1868.	Frederick.
Satterfield, Charles Nathan	1898–1899.	Rock Hall.
Schoolfield, L. H.	1882.	Deer Park.
Scott, Edward Marshall	1898–1899.	Ocean City.
Seyboth, Robert	1879–1882.	Baltimore.
Shepherd, James S.	1895–1896.	Cambridge.
Shipley, Dr. H. C.	1895.	Oldtown.
Shreve, Henry	1894–1899.	Easton.
Shriver, Edwin Thomas	1859–1896.	Cumberland.
Shriver, Howard	1889–1899.	Cumberland.
Slifer, J. Paul	1894–1896.	Burkittsville.
Smith, Prof. Eli	1866.	Emmitsburg.
Smith, George F.	1886–1888.	New Midway.
Smith, Hon. Marion de Kalb	1893–1899.	Chestertown.
Specht, S. P.	1894–1899.	Deer Park.
Sproston, Dr. G. S.	1835–1836.	Baltimore.
Stagg, T. G.	1856–1857.	Ridge.
St. Charles College.	1871–1873, 1895–1899.	Ellicott City.
Steiner, Dr. Lewis H.	1851–1859.	Frederick.
Stephenson, Rev. J.	1860–1870.	St. Mary's City.
Stevenson, Riley Martin	1894–1899.	Pocomoke City.
Stewart, James Robertson	1888–1889, 1894–1899.	Princess Anne.
St. John's College.	1838.	Annapolis.
Stotlemeyer, J. D.	1898–1899.	Hancock.
St. Timothy's Hall.	1866–1867.	Catonsville.
Sylvester, R. W.	1892.	Charlotte Hall.
Tabb, P.	1864.	Oakland Mills.
Thomas, Maj. G. M.	1892.	Charlotte Hall.
Thorpe, Henry W.	1850.	Port Deposit.
Townsend, Mr. G. G.	1898.	Frostburg.
Townsend, Mrs. G. G.	1899.	Frostburg.

NAME.	PERIOD.	PLACE.
Turner, J. S.	1894–1895.	La Plata.
U. S. Naval Academy.	1855–1859, 1861–1876.	Annapolis.
U. S. Surgeon-General's Office.	1822, 1831–1834, 1843–1845.	Ft. Severn.
	1831–1859, 1861–1862, 1864–1892.	Ft. McHenry.
	1824–1835, 1851–1853, 1868–1872.	Ft. Washington.
	1871–1878.	Ft. Foote.
U. S. Weather Bureau.	1871–1899.	Baltimore.

OFFICIALS IN CHARGE.

James E. Cowan, January to April, 1871; Hiram J. Penrod, May, 1871, to September, 1874; W. T. Boyd, September, 1874, to March, 1875; John Kabernagle, April, 1875, to November, 1875; R. J. Bell, December, 1875, to April, 1877; E. W. McGann, May, 1877, to May, 1879; William Black, June, 1879, to July, 1879; John J. Murphey, August, 1879, to October, 1879; Robert Seyboth, November, 1879, to September, 1882; George W. Fegler, September, 1882, to September, 1888; C. P. Cronk, October, 1888, to June, 1895; J. B. Marbury, July, 1895, to June, 1896; George E. Hunt, July, 1896, to May, 1897; F. J. Walz, June, 1897, to 1899.

U. S. Weather Bureau.	1882–1887.	Ocean City.
Valente, Rev. A. X., S. J.	1874–1879.	Woodstock.
Vanderford, Wm. H. Vanderford, Charles H.	1880–1899.	Westminster.
Vannort, Dr. E. A.	1872–1874.	Mt. Airy.
Walz, F. J.	1897–1899.	Baltimore.
Walz, F. J.	1898–1899.	Walbrook.
Warfield, M. W., Jr.	1895.	Lisbon.
Washington Aqueduct Office	1877–1899.	Great Falls.
Washington College.	1855–1864, 1880–1895.	Chestertown.
Watts, Prof. Rowland.	1895–1898.	Westminster.
Weaver, Dr. C. W.	1891–1893.	Taneytown.
Western Maryland College.	1893, 1895–1899.	Westminster.
Woman's College.	1892–1896.	Frederick.
Woods, William Luther	1894–1899.	Baltimore.
Woodstock College.	1870–1899.	Woodstock.
Wroth, H. A.	1895–1899.	Van Bibber.
Young, McClintock	1889–1892, 1894–1899.	Frederick.
Zeigler, Wm. H	1868–1875.	Frederick.
Zumbrock, Dr. A.	1850–1852.	Baltimore.
	1855– (?)	Annapolis.

DELAWARE.

NAME.	PERIOD.	PLACE.
Bateman, John H.	1870–1899.	Dover.
Bishop, Prof. William Herbert	1891–1899.	Newark.
Carnagy, W. C. L.	1883–1899.	Kirkwood.
Delaware College.	1847, 1854–1858, 1888–1899.	Newark.
Ernst, Geo. W.	1889–1890.	Middletown.

Name.	Period.	Place.
Ernst, Mrs. Geo. W.	1890–1899.	Middletown.
Farlow, J. A.	1888.	Viola.
Fisher, Robert W.	1889.	Seaford.
Foulk, Jacob Y.	1874–1899.	Milford.
Gibbons, Dr. Henry	1834–1835.	Wilmington.
Gilman, R. A.	1870– (?)	Milford.
Harter, Prof. George A.	1888–1891.	Newark.
Hedges, Dr. U. D.	1864–1865.	Wilmington.
James, D. F.	1889.	Seaford.
Jester, John S.	1891–1896.	Dover.
McKay, F. C. D.	1894–1896.	Wilmington.
Martin, Richard A.	1857–1858.	Milford.
Mauld, Dr. D. W.	1857–1859.	Georgetown.
Norton, E. E.	1847.	Newark.
Phillips, W. R.	1860– (?)	Milford.
U. S. Signal Service.	1880–1885. 1885–1887.	Delaware Breakwater. Cape Henlopen.
U. S. Surgeon-General's Office.	1825–1859, 1862–1870.	Fort Delaware.
U. S. Weather Bureau. See: U. S. Signal Service.		
Vanhelke, J. M.	1866–1867, 1874–1876.	Delaware City.
Wallace, H. L.	1890–1897.	Seaford.
Wallace, Walter F.	1897–1899.	Seaford.
Wells, Rev. Lewis Wheeler	1890–1899.	Millsboro.
Whittier, A. C.	1865– (?)	Milford.

DISTRICT OF COLUMBIA.

Name.	Period.	Place.
Adams, John Quincy	1820–1821.	Washington City.
Cranch, Judge C. W.	1823–1839.	Washington City.
Gillis, Lieut. J. M.	1838–1842.	Washington City.
Mackee, Rev. C. B.	1860–1863.	Georgetown.
Meigs, General Josiah	1820–1821.	Washington City.
National Deaf Mute College.	1878–1880.	Washington City.
Smithsonian Institution.	1850–1876.	Washington City.
Trunnell, Charles H.	1848–1899.	Georgetown.
U. S. Naval Observatory.	1838–1899.	Georgetown.
U. S. Surgeon-General's Office.	1823–1824.	Washington City.
U. S. Weather Bureau.	1870–1899.	Washington City.
Wallenstein, Jules de	1823–1824.	Washington City.
Washington Aqueduct Office	1877–1899. 1877–1899.	Distributing Reservoir. Receiving Reservoir.
Wiessner, J.	1857–1858.	Anacostia, D. C.

List of Crop Correspondents.

MARYLAND.

Name.	Period.	Town.	County.
Abbott, J. E.	1896–1899.	Annapolis.	Anne Arundel Co.
Acworth, A. E.	1891–1892.	Barron Creek Springs.	Wicomico Co.
	1892–1899.	Mardela Springs.	Wicomico Co.
Adams, G. F.	1894–1895.	Gallant Green.	Charles Co.
Adams, H. C.	1894–1899.	Mechanicsville.	St. Mary's Co.
Addison, C. G.	1894–1899.	Springfield.	Prince George's Co.
Adkins, J. J.	1898–1899.	Wango.	Wicomico Co.
Albaugh, J. H.	1894–1899.	Libertytown.	Frederick Co.
Albaugh, J. L.	1892–1896.	Carrollton.	Carroll Co.
Allen, J. R.	1894–1899.	Rising Sun.	Cecil Co.
Allibone, T. M.	1898.	Allibone.	Harford Co.
Amos, J. W.	1894–1899.	Waterbury.	Anne Arundel Co.
Anderson, J. F.	1894–1897.	Dayton.	Howard Co.
Anderson, W. J.	1894–1895.	Tyaskin.	Wicomico Co.
Andrews, J. B.	1898–1899.	Hurlock.	Dorchester Co.
Atkinson, L. S.	1884–1895.	West.	Somerset Co.
Bacon, T. S.	1893–1895.	Buckeystown.	Frederick Co.
Bailey, J. F.	1894–1898.	Harris Lot.	Charles Co.
Balderston, Elwood	1893.	Colora.	Cecil Co.
Balderston, Geo.	1893–1899.	Colora.	Cecil Co.
Baldwin, Dr. T. M.	1896–1897.	Laurel.	Prince George's Co.
Barkman, Justin	1897–1898.	Flintstone.	Allegany Co.
Barnes, Rev. L. W.	1894–1897.	Jefferson.	Frederick Co.
Barry, J. A.	1898–1899.	Brummel.	Carroll Co.
Barton, John	1894–1895.	Cresaptown.	Allegany Co.
	1896.	Bier.	Allegany Co.
Barton, P. S.	1894–1896.	Line Bridge.	Harford Co.
Bassford, T. J.	1894–1898.	Plum Point.	Calvert Co.
Bay, A. S.	1894–1898.	Vale Summit.	Allegany Co.
	1899.	Emmorton.	Harford Co.
Beall, A. L.	1894–1899.	Collington,	Prince George's Co.
Beall, S. W.	1893–1895.	Contee's.	Prince George's Co.
Bean, J. R.	1894–1895.	Bernard.	Anne Arundel Co.
	1896.	Annapolis.	Anne Arundel Co.
Bean, M. E.	1896.	Fishing Point.	St. Mary's Co.
Beardmore, J.	1894–1895.	Annapolis.	Anne Arundel Co.
Beavin, G. F.	1898.	Crownsville.	Anne Arundel Co.
Beckman, R.	1894–1895.	Swanton.	Garrett Co.
Beckwith, J. M.	1891–1896.	Cornersville,	Dorchester Co.
Bennet, J. S.	1894–1898.	Vienna.	Dorchester Co.
Benson, E. T.	1898–1899.	Royal Oak.	Talbot Co.
Benson, H. R.	1894–1896.	Grafton.	Montgomery Co.
Benzinger, A. M.	1894–1899.	Woodstock.	Howard Co.

Name.	Period.	Town.	County.
Berhand, E.	1896.	Seat Pleasant.	Prince George's Co.
Biggs, William	1896.	Mt. Lake Park.	Garrett Co.
Bird, B. O.	1891–1893.	Princess Anne.	Somerset Co
Bixler, E. C.	1892–1899.	Westminster.	Carroll Co.
Bixler, Uriah	1891.	Westminster.	Carroll Co.
Blackiston, J. F.	1894–1898.	White Plains.	Charles Co.
Blades, J. T.	1894–1896.	Choptank.	Caroline Co.
Blocher, I. M.	1894–1897.	Alesia.	Carroll Co.
Bloodsworth, J. R.	1894–1897.	Mt. Vernon.	Somerset Co.
Boots, Jerry	1894–1896.	Port Republic.	Calvert Co.
Boastion, L. A.	1893–1896.	Clemsonville.	Cecil Co.
Boswell, C. A.	1894–1896.	Pomfret.	Charles Co.
Bourne, J. H.	1894–1896.	Hellen.	Calvert Co.
Bowers, D. H.	1894–1895.	Taneytown.	Carroll Co.
Bragamir, Daniel	1898–1899.	Pisgah.	Charles Co.
Brashears, L.	1894–1899.	Muirkirk.	Prince George's Co.
Brown, D. W.	1894–1896.	Harrison.	Dorchester Co.
Brohann, C. W.	1898.	Salem.	Dorchester Co.
Brown, F. F.	1892–1899.	Boettcherville.	Allegany Co.
Brown, H.	1891.	Chestertown.	Kent Co.
Bruce, Prof. O. H.	1894–1896.	Westernport.	Allegany Co.
Buckler, G. W. L.	1894–1896.	Laurel Grove.	St. Mary's Co.
Bunce, Chas. J.	1891–1897.	Mt. Lake Park.	Garrett Co.
Carlin, Dr. James S.	1894–1899.	Slidell.	Montgomery Co.
Carr, G. W.	1898–1899.	Clarksville.	Howard Co.
Carroll, Dr. W. K.	1898–1899.	Queenstown.	Queen Anne's Co.
Carsins, E. E.	1893–1899.	Aberdeen.	Harford Co.
Chapuis, H. M., S. S.	1896.	Ellicott City.	Howard Co.
Cheston, James, Jr.	1891.	West River.	Anne Arundel Co.
Chapman, W. B. C.	1898.	La Plata.	Charles Co.
Chichester, W. B., Jr.	1894–1896.	Olney.	Montgomery Co.
Chiswell, Jos. M.	1893–1896.	Buckeystown.	Frederick Co.
Clippinger, A.	1896.	Westover.	Somerset Co.
Clokey, W. N.	1896.	Patuxent.	Anne Arundel Co.
Coad, Col. J. E.	1896.	Valley Lee.	St. Mary's Co.
Coad, Prof. J. F.	1896–1897.	Charlotte Hall.	St. Mary's Co.
Cockey, Chas. T.	1893.	Pikesville.	Baltimore Co.
Cockran, L. N.	1896.	Rhodesdale.	Dorchester Co.
Collins, J. R. D.	1898–1899.	Aireys.	Dorchester Co.
Conner, C. J.	1891, 1894–1896.	Frostburg.	Allegany Co.
Corbin, Thomas R.	1894–1899.	Corbin.	Worcester Co.
Coulbourne, Ira N.	1894–1899.	Marion.	Somerset Co.
Coulbourne, W. H.	1898.	Salisbury.	Wicomico Co.
Cox, S., Jr.	1898–1899.	Bel Alton.	Charles Co.
Crisp, Wm. S.	1893–1896.	Brooklyn.	Anne Arundel Co.
Crosby, A. L.	1891–1893.	Catonsville.	Baltimore Co.
Crowther, Dr. D. W.	1898–1899.	Smithsburg.	Washington Co.

NAME.	PERIOD.	TOWN.	COUNTY.
Crowther, G. R.	1893–1895.	Cavetown.	Washington Co.
Cutler, J. P.	1894–1896.	Rock Springs.	Cecil Co.
Curtiss, Prof. G. G.	1893–1899.	Bagley.	Harford Co.
Davis, E. K.	1894–1896.	Woodlawn.	Cecil Co.
Davis, W. S.	1898.	Clement Mills.	Harford Co.
Daymude, John F.	1898–1899.	Boyd's.	Montgomery Co.
De Barrill, Alex.	1891–1896.	Drum Point.	Calvert Co.
Dickerson, W. H.	1894–1899.	Dickerson.	Montgomery Co.
Diehl, Dr. J. S.	1894–1895.	Hancock.	Washington Co.
Dirickson, James B.	1898–1899.	Berlin.	Worcester Co.
Donaldson, R. T.	1892–1899.	Patuxent.	Anne Arundel Co.
Doody, P. H.	1894–1896.	Eden.	Somerset Co.
Doran, E. W.	1892–1893.	College Park.	Prince George's Co.
Dorsey, D. F.	1896.	Dorsey.	Howard Co.
Dorsey, F. H.	1894–1895.	Dorsey.	Howard Co.
Dove, Emmitt.	1898.	Rockville.	Montgomery Co.
Downs, N. T.	1894–1897.	Flintstone.	Allegany Co.
Dubois, C. E.	1894–1896.	Mt. St. Mary's.	Frederick Co.
Dutrow, R. Claude	1893–1899.	Adamstown.	Frederick Co.
Duttera, Amos	1898.	Taneytown.	Carroll Co.
Eckert, W. K.	1898–1899.	Copperville.	Carroll Co.
Edelen, B. M., Jr.	1892–1896.	Bryantown.	Charles Co.
Engel, John	1894–1895.	Gallant Green.	Charles Co.
Engel, John	1896.	Frostburg.	Allegany Co.
Englar, Jos.	1894–1897.	Linwood.	Carroll Co.
Englar, P. B.	1894–1896.	Taneytown.	Carroll Co.
Englar, W. H.	1893–1895.	Bark Hill.	Carroll Co.
Fauble, J. B.	1894–1896.	Burkittsville.	Frederick Co.
Favour, C. R.	1894–1896.	Sykesville.	Carroll Co.
Feldman, Charles	1893.	Edgemont.	Washington Co.
Fenby, William	1893.	Fenby.	Carroll Co.
Finkbine, W. B.	1892–1899.	Annapolis.	Anne Arundel Co.
Fisher, Dr. C. E.	1891–1896.	Rising Sun.	Cecil Co.
Frame, George	1894–1895.	Phoenix.	Baltimore Co.
Frantz, W. W.	1898–1899.	Clear Spring.	Washington Co.
Frazee, G. W.	1896.	Selbysport.	Garrett Co.
Freeman, T. J. A., S. J.	1896.	Woodstock.	Howard Co.
Friel, Capt. Daniel	1898–1899.	Queenstown.	Queen Anne's Co.
Galbreath, A. F.	1891–1898.	Darlington.	Harford Co.
Gall, C. M.	1898–1899.	Thurmont.	Frederick Co.
Garner, Geo. R.	1891.	Chaptico.	St. Mary's Co.
Garrett, J. H.	1894–1896.	Burrsville.	Caroline Co.
Garrett, Medford	1894–1896.	Catlin.	Carroll Co.
Gibson, C. W.	1894–1896.	Aldino.	Harford Co.
Gnagey, John E.	1898–1899.	Accident.	Garrett Co.
Graves, E.	1894–1897.	Hills Point.	Dorchester Co.
Hall, J. I.	1894–1896.	Laurel.	Prince George's Co.

Name.	Period.	Town.	County.
Hall, T. J.	1894–1895.	Loretto.	Somerset Co.
Hamilton, C. R.	1894–1899.	Flintville.	Howard Co.
Hanley, Thos. G.	1891–1896.	Berlin.	Worcester Co.
Hargett, Douglass	1893.	Frederick.	Frederick Co.
Harig, Rev. G. L.	1898–1899.	Pine Orchard.	Howard Co.
Harriott, J. W.	1893–1896.	Chesapeake City.	Cecil Co.
Harriott, M. H.	1894–1896.	Chesapeake City.	Cecil Co.
Harris, C. W.	1892–1893.	Coleman.	Kent Co.
Harris, J. S.	1894–1895.	Cornersville.	Dorchester Co.
Harris, J. S.	1896–1899.	Coleman.	Kent Co.
Hatch, Samuel S.	1898–1899.	Crownsville.	Anne Arundel Co.
Hatch, W. K.	1894–1896.	Crownsville.	Anne Arundel Co.
Hays, Amos H.	1898–1899.	Parkton.	Baltimore Co.
Hays, Edw. P.	1894–1896.	Darnestown.	Montgomery Co.
Hempfling, Geo.	1893.	Delight.	Baltimore Co.
Hendrickson, Ernst	1894–1897.	Dickens.	Allegany Co.
Hendrickson, J. A.	1894–1895.	Cumberland.	Allegany Co.
Hendrickson, M. C.	1893–1896. 1897–1898.	Cumberland. Dickens.	Allegany Co. Allegany Co.
Henshaw, J. J.	1891–1895.	Mechanicstown.	Frederick Co.
Hess, Norman R.	1898–1899.	Harney.	Carroll Co.
Hiberger, R. L.	1894–1898.	Sharpsburg.	Washington Co.
Hicks, W.	1891.	White Plains.	Charles Co.
Hochstedler, William A.	1896–1899.	Cove.	Garrett Co.
Hudson, T. S.	1896.	Crisfield.	Somerset Co.
Hodson, T. T., Jr.	1894–1895.	Crisfield.	Somerset Co.
Holzapfel, H., Jr.	1898.	Hagerstown.	Washington Co.
Hopkins, Dr. H. H.	1891–1899.	New Market.	Frederick Co.
Hopkins, Miss M. D.	1893–1895.	New Market.	Frederick Co.
Hopkins, M. T.	1896–1897.	Highland.	Howard Co.
Hopkins, T. H.	1894–1896.	Cambridge.	Dorchester Co.
Hopkins, W. J.	1894–1896.	Glenville.	Harford Co.
Humbert, W. F.	1892–1893. 1893–1895.	Hancock. Indian Springs.	Washington Co. Washington Co.
Huntzbery, Charles E.	1898–1899.	Boonsboro.	Washington Co.
Huyett, M. H.	1892–1899.	Huyett.	Washington Co.
Ingham, J. W.	1894–1896.	Beckleysville.	Baltimore Co.
Israel, P. H.	1892–1898.	Davidsonville.	Anne Arundel Co.
Jackson, C. S.	1892–1898.	Dailsville.	Dorchester Co.
Jenkins, John J.	1898–1899.	Port Tobacco.	Charles Co.
Joy, Geo. W.	1892–1893.	Leonardtown.	St. Mary's Co.
Jubb, G. A. E.	1896.	Lake Shore.	Anne Arundel Co.
Jump, W. F.	1898.	Cordova.	Talbot Co.
Kantwell, T. J.	1896.	Loretto.	Somerset Co.
Kelly, William T.	1894–1899.	Preston.	Caroline Co.
Kennedy, A.	1898.	St. Mary's City.	St. Mary's Co.
Kester, N. H.	1893.	Pleasant Valley.	Carroll Co.

NAME.	PERIOD.	TOWN.	COUNTY.
Key, J. B.	1898.	Chaptico.	St. Mary's Co.
King, C. M.	1894–1895.	Ellerslie.	Allegany Co.
Kinsell, E. G.	1894–1899.	Green Spring Furnace.	Washington Co.
Knauer, John G.	1892–1899.	Sunnyside.	Garrett Co.
Late, John W.	1898–1899.	Rocky Ridge.	Frederick Co.
Lee, Andrew J.	1894–1899.	Deer Park.	Garrett Co.
Lehman, Chas. F.	1893.	Hagerstown.	Washington Co.
	1894–1895.	Startown.	Washington Co.
Leister, I. Dickson.	1898–1899.	Finksburg.	Carroll Co.
Lohr, P. P.	1892–1899.	Bittinger.	Garrett Co.
Loose, W. E., Jr.	1898.	Clear Spring.	Washington Co.
Lord, Geo. E.	1893.	Brookview.	Dorchester Co.
McAvoy, Hugh.	1894–1897.	Clarkson.	Howard Co.
McBride, G. W.	1892–1895.	Boonsboro.	Washington Co.
McCoombs, W. S.	1891.	Havre de Grace.	Harford Co.
McDaniel, James E.	1899.	McDaniel.	Talbot Co.
Maitland, Thomas L.	1898–1899.	Sudley.	Anne Arundel Co.
Malone, Col. Lemuel.	1891–1893.	Salisbury.	Wicomico Co.
Marsh, Dr. W. H.	1894–1899.	Solomon's.	Calvert Co.
Meier, Prof. H.	1896–1899.	Taneytown.	Carroll Co.
Mellor, E. M.	1894–1895.	Sykesville.	Carroll Co.
Metcalf, H. D.	1893.	Landover.	Prince George's Co.
	1894–1896.	Bladensburg.	Prince George's Co.
Miller, H. H.	1898–1899.	Sandy Spring.	Montgomery Co.
Miller, J. A.	1891–1899.	Keedysville.	Washington Co.
Miller, J. S.	1891–1899.	Grantsville.	Garrett Co.
Miller, Joseph L.	1898–1899.	Smithsburg.	Washington Co.
Minnick, G. W.	1893.	Easton.	Talbot Co.
Minnick, S. P.	1892–1893.	Easton.	Talbot Co.
Mitchell, J., Jr.	1896.	Havre de Grace.	Harford Co.
Mitchell, J. Wm.	1893–1896.	Havre de Grace.	Harford Co.
Mitchell, Dr. Jas. A.	1892–1899.	Mt. St. Mary's.	Frederick Co.
Moore, S. H.	1896–1898.	McDonogh.	Baltimore Co.
Moores, John	1898–1899.	Bel Air.	Harford Co.
Mullikin, Percival	1891–1892.	Trappe.	Talbot Co.
Myers, C. C.	1894–1895.	McKinstry's Mills.	Carroll Co.
Myers, J. M.	1896.	Westminster.	Carroll Co.
Naudain, J. M.	1894–1896.	Singerly.	Cecil Co.
Nichols, C. E.	1898–1899.	Nichols.	Caroline Co.
Nichols, E. J.	1894–1897.	Nichols.	Caroline Co.
Nicholson, R. G.	1898–1899.	Chestertown.	Kent Co.
Noyes, E., Jr.	1893.	Port Deposit.	Cecil Co.
Nutter, G. D.	1893–1896.	Cornersville.	Dorchester Co.
Nyce, A. W.	1894–1895.	Garrison.	Baltimore Co.
Oldfield, Clarence	1891.	Ellicott City.	Howard Co.
Oswald, E. I.	1898–1899.	Chewsville.	Washington Co.
Parran, N. D. S.	1891.	St. Leonard's.	Calvert Co.

NAME.	PERIOD.	TOWN.	COUNTY.
Parsons, M. A.	1894–1896.	Salisbury.	Wicomico Co.
Patterson, Prof. H. J.	1898–1899.	College Park.	Prince George's Co.
Perry, Jas. R.	1892–1896.	Harris Lot.	Charles Co.
Pfeiffer, Geo. B.	1892–1893.	Hyattsville.	Prince George's Co.
Phelps, Dr. F. P.	1894–1899.	Mt. Holly.	Dorchester Co.
Plummer, J.	1896–1898.	Jewell.	Anne Arundel Co.
Posey, A. B.	1898–1899.	Doncaster.	Charles Co.
Price, P. T.	1898.	Kent Island.	Queen Anne's Co.
Pumphrey, B. F.	1892–1896.	Benfield.	Anne Arundel Co.
Quidort, E. F.	1892–1895.	Federalsburg.	Caroline Co.
Ramsell, F. C.	1891–1899.	Denton.	Caroline Co.
Reichard, D. W.	1892–1896.	Hagerstown.	Washington Co.
Reynolds, W. P.	1892–1896.	Rising Sun.	Cecil Co.
Rhoderick, G. C., Jr.	1891–1893.	Middletown.	Frederick Co.
Rice, D. H.	1898–1899.	Towson.	Baltimore Co.
Richardson, Dr. H.	1898–1899.	Great Mills.	St. Mary's Co.
Richmond, Fred.	1891.	Pope's Creek.	Charles Co.
Rieman, H.	1894–1896.	Tunis Mills.	Talbot Co.
Rinehart, W. C.	1892–1896.	Linwood.	Carroll Co.
Roberson, W. T. B.	1892–1896.	Rising Sun.	Cecil Co.
Roe, A. B.	1892–1898.	Greensboro.	Caroline Co.
Roe, Frederick P.	1898–1899.	Greensboro.	Caroline Co.
Rouzer, John H.	1898–1899.	Thurmont.	Frederick Co.
Royer, P.	1896–1899.	Keyser.	Garrett Co.
Russell, Mrs. S. S.	1892–1893.	Edgewood.	Harford Co.
Sappington, G. T.	1892–1895.	Elvaton.	Anne Arundel Co.
Scholl, L. B.	1892–1896.	Dickerson.	Montgomery Co.
Scott, Forrest	1892–1896.	Bellevue.	Talbot Co.
Scott, Jas. T.	1892–1896.	Robert's.	Queen Anne's Co.
Seavolt, W. B.	1892–1896.	Lock 53.	Washington Co.
Shaw, J. T.	1894–1896.	Charlotte Hall.	St. Mary's Co.
Sherman, Raleigh	1894–1896.	Sharpsburg.	Washington Co.
Shreve, Henry	1894–1897.	Easton.	Talbot Co.
Shriver, Howard	1891–1899.	Cumberland.	Allegany, Co.
Silver, Albert P.	1899.	Glenville.	Harford Co.
Slobach, C. W.	1894–1895.	Sunnyside.	Garrett Co.
Smith, F. O.	1898.	Dunkirk.	Calvert Co.
Smith, G. F.	1892–1896.	Woodsboro.	Frederick Co.
Smith, Jesse	1898–1899.	Linwood.	Carroll Co.
Smith, Hon. M. de Kalb	1896.	Chestertown.	Kent Co.
Smith, S. L.	1894–1896.	Graceham.	Frederick Co.
Snowdon, Francis	1898–1899.	Ashton.	Montgomery Co.
Specht, S. P.	1894–1898.	Deer Park.	Garrett Co.
Spedden, C. F.	1894–1896.	James.	Dorchester Co.
Speers, Solomon P.	1898–1899.	Earleigh Heights.	Anne Arundel Co.
Sprogel, D. S.	1892–1896.	Annapolis.	Anne Arundel Co.
Stam, C. F.	1894–1896.	Chestertown.	Kent Co.

NAME.	PERIOD.	TOWN.	COUNTY.
Stansbury, H. H.	1891.	Hampstead.	Carroll Co.
Steuart, R.	1898–1899.	Jewell.	Anne Arundel Co.
Stevenson, R. M.	1884–1896.	Pocomoke City.	Worcester Co.
Stewart, J. R.	1896.	Princess Anne.	Somerset Co.
Stewart, P. H.	1894–1896.	Jewell.	Anne Arundel Co.
Stokes, Dr. S. A.	1898–1899.	Cornersville.	Dorchester Co.
Sumwalt, W. J.	1892.	Thurston.	Frederick Co.
Sweet, C. T.	1894–1896.	Swanton.	Garrett Co.
Sweet, William W.	1894–1899.	Mountain Lake Park.	Garrett Co.
Tanner, W. P.	1894–1895.	Mattapex.	Queen Anne's Co.
Talbot, J. F.	1891.	Chaneyville.	Calvert Co.
Taylor, B. F.	1892–1899.	Bradshaw.	Baltimore Co.
Thomas, W. Bruce,	1894–1899.	Malcolm.	Charles Co.
Thompson, William J.	1894–1899.	Scarboro.	Harford Co.
Tippett, W. C.	1892–1896.	Mattawoman.	Charles Co.
Turner, H. A.	1892–1896.	Bryantown.	Charles Co.
Turner, John C.	1892–1896.	Millington.	Kent Co.
Twilley, G. C.	1894–1895.	Twilley.	Wicomico Co.
Tydings, J. H. A.	1898–1899.	St. Margaret's.	Anne Arundel Co.
Vickers, T. J.	1894–1896.	Lankford.	Kent Co.
Wallace, H. L.	1896.	Sudlersville.	Queen Anne's Co.
Waller, James A.	1899.	Hebron.	Wicomico Co.
Walls, S. H.	1894–1898.	Sudlersville.	Queen Anne's Co.
Walsh, D. E.	1898.	Carrollton.	Carroll Co.
Walsten, G. B.	1896.	Campbell.	Worcester Co.
Warfield, Jara	1894–1896.	Florence.	Howard Co.
Warfield, W. W., Jr.	1894–1895.	Lisbon.	Howard Co.
Watkins, Benj.	1891–1897.	Rutland.	Anne Arundel Co.
Watts, Prof. R.	1896.	Westminster.	Carroll Co.
Weaver, Dr. C. W.	1891–1892.	Taneytown.	Carroll Co.
Welch, E. O.	1891–1899.	Bristol.	Anne Arundel Co.
Welch, Wm. H.	1899.	Church Hill.	Queen Anne's Co.
Weller, Henry A.	1898–1899.	Graceham.	Frederick Co.
Wells, Thomas	1894–1896.	Houcksville.	Carroll Co.
Wessels, W. B.	1899.	McDonogh.	Baltimore Co.
West, S. W.	1891.	Greensboro.	Caroline Co.
Whitthuhn, J. W.	1894–1895.	Gott's.	Anne Arundel Co.
Williams, P. P.	1898.	Doncaster.	Charles Co.
Williams, T. J. C.	1891.	Hagerstown.	Washington Co.
Willis, W.	1891, 1898.	St. Michael's.	Talbot Co.
Wills, P. R.	1894–1896.	Bel Alton.	Charles Co.
Wilson, A. C.	1892–1896.	Jewell.	Anne Arundel Co.
Wilson, Chas. C.	1892–1895.	Queenstown.	Queen Anne's Co.
Wilson, M. R.	1894–1895.	Dailsville.	Dorchester Co.
Wilson, M. R.	1896.	Cumberland.	Allegany Co.
Wilson, R. C.	1892–1896.	Rawlings.	Allegany Co.
Witherow, W. W.	1896–1899.	Taneytown.	Carroll Co.

NAME.	PERIOD.	TOWN.	COUNTY.
Witmer, D. J.	1897–1899.	Beaver Creek.	Washington Co.
Witmer, Joseph	1893–1898.	Beaver Creek.	Washington Co.
Wolf, Geo. H.	1898–1899.	Kump.	Carroll Co.
Wood, Z. H.	1894–1897.	Allen's Fresh.	Charles Co.
Wroth, Emory S.	1894–1896.	Chestertown.	Kent Co.
Wroth, H. A.	1894–1899.	Van Bibber.	Harford Co.

DELAWARE.

NAME.	PERIOD.	TOWN.	COUNTY.
Bateman, A. A.	1898.	Dover.	Kent Co.
Bishop, Prof. W. H.	1896–1899.	Newark.	New Castle Co.
Brown, E. B.	1898–1899.	Seaford.	Sussex Co.
Carnagy, J. S.	1897.	Kirkwood.	New Castle Co.
Carnagy, Wm.	1896.	Kirkwood.	New Castle Co.
Carnagy, W. C. L.	1891.	Kirkwood.	New Castle Co.
Eliason, A. S.	1892–1896.	Mt. Pleasant.	New Castle Co.
Foulk, J. Y.	1892–1899.	Milford.	Kent Co.
Gray, C. E.	1894–1895.	Kirkwood.	New Castle Co.
Hamilton, B. F.	1898.	Newark.	New Castle Co.
Hegeman, E. D.	1894–1895.	Laurel.	Sussex Co.
Holden, G. F.	1898–1899.	Milford.	Kent Co.
Jackson, W. B.	1898.	Hockessin.	New Castle Co.
Jester, J. S.	1896.	Dover.	Kent Co.
Nelson, J. B.	1898.	St. George's.	New Castle Co.
Nelson, J. F.	1892–1896.	Kirkwood.	New Castle Co.
Sullivan, William	1898–1899.	Farmington.	Kent Co.
Wells, Rev. L. W.	1894–1899.	Millsboro.	Sussex Co.

OUTLINE OF PRESENT KNOWLEDGE OF THE METEOROLOGY AND CLIMATOLOGY OF MARYLAND

BY

F. J. WALZ

INTRODUCTION.

No factor among the forces of nature influences man's temporal well-being more than climate. The variations of climatic elements within which he can live with comfort are very narrow: a change in the temperature of a few degrees, either below or above the normal range, sets him fighting for his life. If this is true of man it applies still more powerfully to every other living thing on the earth's surface, animal or vegetable, since man alone is able to employ the inventions of reason to modify the forces of nature. Climate and weather also play a very important part in changing the configuration and nature of the surface of the earth itself.

Alternating seasons and irregular weather changes have interested man and engaged his attention from the earliest times. Continual observations led to the gradual development of meteorology as it is to-day, which, however, did not rank as a science until the invention of the barometer and thermometer made possible the accurate measurements of the governing elements of the weather.

Meteorology, of which climate is a part, has been spoken of as "the border land where physics, chemistry and geology meet." It may justly claim kinship to these, as to nearly every other branch of scientific research that has received a special name of its own.

The definitions of the term climate are almost as innumerable as

its relations, each depending upon the point of view from which the subject is surveyed. The biologist divides the earth into life zones which are determined by climatic conditions. He thus defines climate in its relation to life. The ethnologist and historian, following the development of racial and national characteristics, find conjoined with the rise and fall of empires the potent influences of climatic environment. Color, temperament, religious belief, in fact, all the positive qualities that distinguish the individual from its neighbor are determined by climatic conditions. Thus climate may be defined in its relation to civilization. To the political theorist climate is one thing; to the merchant another; to the agriculturist and soil chemist yet another; and so on. Climate, however, includes all these views. Simply stated, it is the average of the atmospheric conditions of a region—the temperature, precipitation, wind, etc.—and their relations to the earth and its inhabitants.

It is the main purpose of this paper to determine and set forth in a concise manner the average climatic conditions and the departures therefrom, of which records have been preserved, that have occurred in the past in Maryland, and from which some idea may be gained as to what should be reasonably expected in the future.

The study and knowledge of the climate of a place is useful to all —merchant, banker, business man, mechanic, engineer, doctor, lawyer, and day laborer—but none are probably more affected by the weather and climate than the tiller of the soil. The farmer depends upon the weather for his plowing, planting and seeding, as well as for the selection of the products best suited for his farm. The conditions of life at present all tend to a higher state of civilization and intelligence, and successful competition in the struggle requires men of all vocations to be well-informed; to none does this apply more strongly than to the farmer. To-day it requires as high an order of intelligence to conduct a farm with success and profit as is demanded in any other calling, and a general knowledge of climate in its relations to plant life is a matter of the first importance.

In the preliminary study of the climate of Maryland, which follows, it has been attempted to present general facts as far as possible,

leaving the application of such facts to special investigations to be made by those engaged therein. An exhaustive study is not claimed, since the deductions are based on but a brief period of observation. The results and deductions from the observations of weather elements, mainly temperature and precipitation, that have been made in the state, are given, rather than a vast amount of tabulated records. Tables have been introduced only when and where it was thought necessary to give in full the information that might be needed.

In the preparation of this article all the data available have been carefully reviewed and studied.[1] The object has been to set forth in a brief and concise way the climatic conditions of Maryland in its various physiographic divisions, and while it consists, primarily, of a mere summary of past records, rather than an exhaustive treatise upon their causes and minute distribution, the purpose has been to present the data in such form as may be suitable to all desiring information regarding climate and weather in Maryland. It is hoped that it will adequately meet the temporary needs, at least, of those seeking such knowledge, whether student, merchant, professional man, or farmer. In other papers or volumes which are to follow, it is intended to enter into more minute detail regarding the various climatic phenomena for the state, together with their causes and distribution. This is especially planned with respect to rainfall distribution and the irregularity which attends it. As yet the observations have not been sufficiently extended and systematized to form a basis for a minute study.

General Discussion.

Before taking up the study of local conditions, it may be well to give briefly the more important of the general laws involved in producing the climate of a place. These will be found stated at length in standard works on meteorology.

[1] The writer here acknowledges his indebtedness to Mr. E. C. Easton, of the local Weather Bureau force, for valuable assistance. The charts of normal temperature and precipitation are his work, and he also aided in the large amount of tentative work preliminary to the general studies, as well as in parts of this article. Mr. J. A. Barry, also of the local force, aided in tabulating statistics from the Baltimore records.

Climate, in its modern acceptation, signifies that peculiar state of the atmosphere in regard to heat and moisture which prevails at any given place, together with meteorological conditions generally, in so far as they exert an influence on animal and vegetable life.

The infinitely varied character which climate displays may be referred to the combined operation of different causes, which are chiefly reducible to these four:

Latitude—distance from the equator.

Elevation—height above sea-level.

Distance and location—with reference to the sea.

Prevailing winds.

These may be regarded as forming the great basis of the law of climate. They do not work independently, but are correlated. Wherever any one of the factors has undue prominence it will affect the climate of that place more than will the others; as, for example, elevation overcomes the influences of latitude in the case of snow-capped mountains in the equatorial regions, and the effects of the Gulf stream make one forget that the green shores of England are situated on the same parallel as icy Labrador.

There are still other factors involved in the formation of the climate of a place besides those already mentioned. They are mainly subordinate, however, and are frequently difficult to classify, especially when they arise from a combination of the larger determinant causes. They will be mentioned later under the headings to which they most properly belong.

The influence of latitude upon the climate of a place is most noticeably felt with regard to temperature. As is well known, this is due to the inclination of the earth's axis from the perpendicular; the rays of the sun fall more slantingly as the distance from the equator increases, and the amount of heat received on the surface of the earth by direct solar radiation is correspondingly lessened. To the same cause is attributable the alternate seasons of the temperate zones.

Elevation above sea-level has a modifying effect upon climate in several ways. The decrease in temperature is perceptibly felt in the ascent of mountains; the rate of decrease is variable—changing with

the latitude, situation, amount of moisture in the air, hour of the day and season of the year—but that usually adopted in the reduction of temperature for height is 1° for every 300 feet. Elevation frequently affects climate with respect to rainfall, especially where mountain ranges are found running at right angles to moisture-bearing winds, which, cooled in their ascent, lose their capacity for aqueous vapor. Rain falls on the windward slopes, and the air passes over the summits cool and dry to the region beyond.

The conserving effect of the proximity of extensive bodies of water upon the temperature of a place is very great, and forms one of the main modifying influences of the climate of Maryland. The distribution of land and water accounts largely for the marked deviation of the isothermal lines from the parallels of latitude, and is also responsible to a great degree for the formation of permanent areas of high and low pressure, which, in turn, aid in determining the direction of prevailing winds, and whether such winds are moisture-bearing or dry.

Let us consider a little more fully the relations of land to water in the formation of climate. Of all known substances water has the greatest *specific heat*, this being, as compared to the rocks and soil composing the earth's crust, in the proportion of 4 to 1. Owing to this essential difference between land and water with respect to heat, climates have been grouped into two great classes of Oceanic or Insular and Continental.

Oceanic climates are the most equable of all, showing for the same latitude the least differences between the mean temperatures of the different hours of the day, or those of the months of the year, and are at all times least subject to radical changes of temperature.

Continental climates are characterized by great extremes of temperatures, as there are no conserving influences exerted by water areas. Relatively high temperatures prevail in summer and low temperatures in winter, and a greater diurnal range is also experienced.

Prevailing winds are the simple result of the relative distribution of atmospheric pressure, their direction and force being due to the

flow of air from a region of higher toward a region of lower pressure, or from where there is a surplus to where there is a deficiency of air.

The climate of a country depends very largely upon the prevailing winds. If the winds are such that in whatever direction they blow they come over a water surface, the climate over this area will be even and regular, and the range in temperature between winter and summer will be slight. This is true of oceanic or insular climates, which obtain largely over the islands of the ocean and on the land bordering on the eastern shore of the ocean in the north middle latitudes. If the winds blow at one time over the surface of large bodies of water, and at another time over the land, the climate will be irregular or semi-continental. Such a climate obtains on the land bordering on the western shores of the ocean in North America. Again, if the winds from any direction blow over land surfaces before reaching the place under consideration, they will give irregular climatic conditions, being warmer when the winds blow from the south and colder when they are from the north. Such a climate is purely continental and obtains in the interior of large land areas. A place may be so located that the winds blow almost continually from the same direction, in which case the climate would be even, generally fair and dry. Such a climate obtains in the trade-wind regions. Again, a place may be so located that there is little or no wind, with clear weather prevailing, in which case there would be an equal temperature. Such a climate prevails in the *horse latitudes*. Or, finally, the climate may have little or no wind, and be extremely humid and rainy, as obtains in the *doldrums*, or equatorial regions.

The soil of a place and its covering also have an important bearing on its climate. Sandy soil, being a poor conductor of heat, has great influence in raising the temperature of air by day, and, through its great radiating properties, of cooling it by night. Of all surfaces that the earth presents to the influence of solar and terrestrial radiation, an extent of sand is accompanied by the most extreme fluctuations of temperature. On the other hand, extensive forests tend to mitigate the extremes of temperature by distributing the diurnal changes more equably, and to modify the effects of rainfall by conserving the moisture received from the clouds.

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Vital elements of climate are the deviations which occur from the seasonal averages, such as periods of extreme heat and cold, humid and dry air, liability to storms attended by wind, rain, hail or snow, and prevalence of fogs. Cyclonic and anticyclonic conditions, and the features connected with their irregular movements, also enter into the complicated study. To the irregular movements of transient pressure areas are traceable the quickly changeable phenomena known as weather. The part played by the permanent areas of high and low pressure is not so readily discernible for short periods, although they have a measurable value in determining the cumulative effects which we call climate.

Now, among these various kinds of climate, Maryland has a place, and as it is located in middle latitude and upon the western shore of the ocean, with a great continent to the west of it, and the prevailing winds westerly, its climate might be classed as continental. But while the prevailing winds are westerly, they are far from being universally so over this section, for, as is well known, winds can blow any day from any direction. Maryland's climate thus is really semi-continental. This variability in the wind direction is caused by the passage across the United States of cyclonic and anticyclonic areas. A close study of the characteristics, movements and frequency of these cyclonic and anticyclonic areas is of prime importance for a complete understanding of the climatic conditions of Maryland. These will be discussed under the head of meteorology or weather.

METEOROLOGY OR WEATHER.

Permanent Pressure Areas.

In taking up the distribution of atmospheric pressure, the first class to be considered will be the so-called permanent pressure systems. The formation of permanent areas of high and low pressure is due mainly to the intense heat of the tropical regions, the irregular distribution of land and water areas, and the general circulation of the atmosphere. The most pronounced types are naturally found in

connection with very large land areas bordering on water areas also having great extent, as is the case with the Asian continent and the adjoining waters. The shifting of the pressure systems over these areas, summer and winter, determines the general wind direction and the wet and dry seasons of that region. In the summer when the land surfaces are heated and the water surfaces are warming up but slowly, a general area of low pressure forms over the interior of the continent, the prevailing winds, heavily laden with moisture, blow from the ocean, and the moisture is precipitated on the slopes of the lofty mountains as the air is cooled in its ascent to higher altitudes. In winter the conditions are reversed. These winds are known as the monsoons, and, with their accompaniments, form the most striking features of the climate of that section.

With regard to the prevalence of similar conditions in our country, Ferrel[1] states:

"On the continent of North America we have monsoon influences similar to those of Asia, but not nearly so strong, because the extent of the continent, and consequently the annual range of temperature, are not so great. They are, for the most part, not sufficiently strong to completely overcome and reverse the current of the general circulation of the atmosphere, and so to produce a real monsoon, but they cause great differences between the prevailing directions of the winter and summer winds.

"In the summer the whole interior of the continent becomes heated up to a temperature much above that of the oceans on the same latitudes on each side—indeed, above that of the Gulf of Mexico and the Pacific Ocean on its southern and southwestern borders. The consequence is that the air over the interior of the continent becomes more rare than over the oceans, rises up, and flows out in all directions above while the barometric pressure is diminished, and the air from all sides, from the Atlantic on the east, the Pacific Ocean on the west, the Gulf of Mexico on the south, and the polar sea on the north, flows in below to supply its place. On the east the tendency to flow in is not strong enough to counteract the general easterly motion of the air at the earth's surface in the middle latitudes, and to cause a westerly current, but it simply retards the general easterly current and gives rise to a greater prevalence of easterly winds along the Atlantic sea-coast during the summer season. On the southern and southeastern coast, in connection with the deflection [already] . . . . referred to, it causes the prevailing winds to be southerly and southeasterly instead of northeasterly, as they otherwise would be in these trade-wind latitudes. It is precisely the same effect as is produced in the region southeast of China . . . . The monsoon influence in the Mississippi valley and westward

[1] A Popular Treatise on the Wind, Wiley, 1889, pp. 214-216.

is much strengthened by the gradual slope from this valley up to the high plateaus east of the Rocky Mountain range . . . . so that when this slope in summer becomes heated the surface air tends to flow up it toward the mountain range, and causes winds, which otherwise would be southerly ones, to become more southeasterly, and southwesterly winds to become southerly ones.

"In winter the thermal conditions over the continent are reversed. The interior of the continent is now the coldest part, and it is especially colder than the surrounding oceans at that season. It has also very high plateaus and mountain ranges. The air, therefore, of the lower strata, and especially those next the earth's surface, now tends to flow out in all directions to the warmer oceans and the Gulf of Mexico, and especially to run down the long slope of plateau from the Rocky Mountains into the Mississippi valley. The effect over the whole of the United States east of the Rocky Mountains is to cause the winds, which otherwise would be westerly and southerly, to become generally northwesterly winds, instead of southerly and southwesterly ones, as in summer. There is not a complete monsoon effect, but simply a great change between winter and summer in the prevailing direction of the winds. In Texas, however, and farther east along the northern border of the Gulf, the effect is somewhat that of a complete monsoon. In New England and farther south in the Eastern States the monsoon effect is to cause the prevailing winds to be from some point north of west, instead of south of west as in summer."

The permanent pressure systems influencing the climate of Maryland are: The high pressure area which stretches across the Atlantic ocean between parallels of latitude 40° and 60° throughout the year; the low pressure area extending over the North Atlantic in the vicinity of Greenland, which tends to fill up in summer; and the high pressure area which forms over the northern Rocky Mountain plateau in winter, and in summer is succeeded by a low pressure area in that region.

The Atlantic high has a slow movement to the north of parallel 30° in the summer and to the south of that parallel in winter; it also has a long, irregular movement to the east and west. In January it extends from longitude 40° west to longitude 60° west, just south of the 30th parallel. By March it is to the southwest of the Azores, in the vicinity of the 25th parallel. The pressure increases to 30.25 inches by June, and is then located between 30° and 40° west longitude, and lies almost on the 30th parallel. It attains its greatest intensity of 30.30 inches in July, and approaches near the 35th parallel. By October the high has passed to the southwest of the Azores, and lies between 30° and 40° west longitude.

The North Atlantic low area has its minimum pressure of 29.50 inches in January, and its center lies just east of Greenland. In July this pressure is increased until it reaches 29.90 at the center.

The shifting of areas of high pressure in winter to areas of low pressure in summer, in the northwestern districts, has already been described.

To sum up the conditions, then, for winter and summer, they are as follows: In winter a high area is located in the Middle Atlantic about the 30th parallel, a low area in the North Atlantic near Greenland, and a high area over the Northwest states. This distribution of pressure produces strong westerly winds over the entire eastern Atlantic coast, carrying the cold conditions of the interior to the Atlantic states. In summer the high area in the Middle Atlantic has moved slightly northward, with increased energy, the low in the North Atlantic has been gradually diminishing in intensity, and the high over the interior has been replaced by an area of low pressure. This arrangement tends to give southerly winds, but, on account of the influence of the earth's rotation, they are changed to southwest, so that during the summer season the prevailing winds over the eastern coast, including Maryland, are from the southwest.

The irregular and uncertain movements of the Atlantic high area to the east, or west, probably influence to a great degree the weather for a season over the eastern coast. This likelihood has been well brought out in a study by Dr. O. L. Fassig[1] of the conditions for March, 1898. In carefully charting the pressure distribution for that month over the Atlantic ocean, he found that the area of high pressure had shifted very decidedly to the west of its usual position during March, and had extended over a large part of the eastern United States. The probable result of this shifting position was the unusually warm conditions which prevailed during March, 1898, as compared with the normal for that month. The conditions for March just past, 1899, were similarly charted; they show that the Atlantic high area had assumed a nearly normal position, and that this condition brought about the nearly normal temperatures during that month in the Middle Atlantic states.

[1] From the manuscript notes.

Transient Pressure Areas.

Passing from a consideration of the general atmospheric circulation, and the permanent pressure areas, it becomes necessary to examine the more local and transient conditions of increased or diminished air pressure, that form at irregular periods and frequently overspread large areas of country. These, too, result from physical causes, and arise from the continued, but never ending, endeavor to restore the atmospheric equilibrium, as constantly disturbed by the unequal distribution, or more properly, the unequally distributed effects of solar energy.

The irregular formation and movement of these large air masses, differing with regard to pressure, heat and moisture, are included under two heads, cyclonic and anticyclonic areas of low and high pressure.

Cyclonic areas, or cyclonic circulation, or cyclonic movement, may be described as follows: The area is composed of a large mass of moving air, disk-shaped, its horizontal extent being from three hundred to fifteen hundred miles, and its vertical extent from a half mile to three miles. The pressure is lowest at the center of this area and gradually increases outward. The air circulates spirally inward and upward towards the central low or core, the motion being negative, or opposite to that of the hands of a watch lying on the table face upward. The velocity of the circular motion depends to a great extent upon the gradient or steepness of the depression, *i. e.*, the difference per unit distance between the air pressure at the core and at the outer edge of the area. As the pressure at the center remains lowest, and as the surface winds flow into it from all sides, there must be an upward as well as a horizontal movement of the air circulation. This cyclonic area, then, is an immense upward whirl or thin eddy of the atmosphere. It does not remain stationary, but moves in the middle latitudes to the east, the energy or strength of the circulation sometimes increasing, sometimes diminishing, the tendency in general being towards an increase as it approaches the Atlantic coast. The rate of motion eastward, in the United States, is about 600 miles per day. Its area also frequently enlarges or contracts during its pro-

gress. Associated with this cyclonic circulation is: unsettled weather, increasing cloudiness, rain or snow, brisk to high warmer southerly winds on the south side; clearing and colder northwest winds on the west and north sides.

Anticyclonic circulation, as the name would indicate, is the opposite to that of cyclonic. A large mass of moving air circulates around a center; the pressure at the center is highest and decreases outward. The winds circulate with the hands of a watch. The weather, associated with the anticyclonic circulation, is usually clear and cool, with northerly and westerly winds on the front side, and easterly winds in the rear. An exception to this condition occurs in Maryland and generally over the Atlantic states in the summer time, when an anticyclonic area settles down over the south Atlantic states, when it sends out warm air from the southern regions, which is further heated in its passage over the land areas, giving hot southwesterly winds, and causing the hot terms of the midsummer months.

The cyclonic areas display greater energy in their circular whirl and progressive movement than the anticyclonic areas. The cyclonic areas are what are popularly known as storms, and they produce all the abrupt changes in the weather conditions, except the cold waves of winter, which depend upon the active anticyclonic areas closely following. They are much more frequent in winter than in summer, and follow quite regular tracks in their eastward movement. Either the cyclonic or the anticyclonic conditions may assume such large proportions as to cover one-half of the United States, and may require several days for their passage across the entire country. The average period is about three days. The longer-lived cyclonic areas are confined principally to the colder months.

The shifting highs and lows nearly all cross the North American continent from west to east. By far the greater number, about 73 per cent., of the cyclonic areas have their origin either in the far northwest, on the North Pacific coast, or over the Rocky Mountain Plateau region. The main track of these storms is eastward, converging towards the 45th parallel near the Lake region, and then following the northern border of the United States to the St. Law-

FIG. 1.—ROOF OF BUILDING SHOWING INSTALLATION OF INSTRUMENTS, BALTIMORE.

FIG. 2.-INTERIOR OF WEATHER BUREAU OFFICE, BALTIMORE.

rence valley. A frequent course of the northwest storms is southward to the lower Mississippi valley, where they again change their direction and pass northeast up the Ohio valley to the St. Lawrence, thus forming a part of the main track so far as Maryland is concerned. The Gulf storms, which form about 12 per cent. of the entire number, usually pass northeast to the west of the Alleghany range of mountains and to the lower Lake region, but they frequently move along the Gulf coast to the Atlantic and then north-northeast. It is these storms that come from the Gulf region and the Southern Plateau and pass along to the west of the Alleghany range, or else move eastward to the Florida coast and then northeastward along the Atlantic shore, that have the greatest influence in causing the abrupt weather changes that occur over Maryland. An average of 4 or 5 storms move in from the West Indies and pass up the Atlantic seaboard each year. These are the most violent and destructive of all.

The highs have their origin in winter usually in the northwest territory, but in summer they move in from the middle Pacific coast. They all travel eastward in waves across the continent, and tend to join the permanent high pressure area over the middle Atlantic.

As the great majority of storms in their eastward movement pass near Lake Erie and Lake Ontario, Maryland lies about 300 to 500 miles south or southeast of the main storm track of North America. The influence, however, of the storm areas in their passage northeastward usually extends to the Atlantic coast, and therefore includes this state. A detailed five-year study of these, as well as of the anticyclonic areas, has been made in order to ascertain the prevailing weather phenomena over Maryland, associated with the movement of these areas, during that period.

Cyclonic and Anticyclonic Conditions for Maryland.

In investigating the cyclonic and anticyclonic conditions produced in this locality by the passage of transient areas of atmospheric circulation, the synoptic weather charts for the five-year period, 1894-1898, were carefully examined, Baltimore being used as the place of reference. All cyclonic and anticyclonic areas, whose centers at any time during their passage moved within one thousand miles of

Baltimore, were considered. The character of the weather and direction of the winds, as observed at Baltimore at the time these centers were in certain definite positions with reference to that city, were noted. These positions of the pressure system centers were determined as follows: The circular geographical area confined within a radius of 1,000 miles of Baltimore was divided into thirty-two parts, or tracts, by N-S, E-W, NE-SW, and NW-SE lines, and by concentric circles at the distances of 100, 400, 700 and 1,000 miles respectively from the pressure center.

As the areas of atmospheric circulation for the five years considered reached the thousand mile limit from Baltimore, their course was followed. With the successive location of their centers in one or another of the small tracts the weather conditions obtaining at Baltimore at the same time were noted, and an average of these conditions with reference to each particular tract was computed.

These results were then merged into figures, representing hypothetical cyclonic and anticyclonic areas. In plotting these figures, the center of the pressure system has been used as the center of the diagram, and the surrounding tracts, graphically treated, presented the average local conditions that prevailed with Baltimore located in such direction and at such distance from the center of the pressure area system.

These figures were originally prepared for each calendar month, and for the cyclonic areas were separately charted for the storms originating north, and for those forming south, of the fortieth parallel. The original plottings will be studied in the text, but for illustrative purposes in this volume, months have been grouped into seasons, and the two classes of cyclonic storms combined into one. In addition to these figures, tables are given showing whether rain occurred in 12, 24, 36 or 48 hours, following the location of Baltimore in any particular tract with relation to the pressure center.

A study of the figures and tables, combined with a general knowledge of the atmospheric circulation, should be of value in the forecasting of the probable weather conditions, when, in the future, the pressure systems are found on the weather maps to lie in a definite direction and at a definite distance from Baltimore.

To begin with an examination of the frequency and successive location of cyclonic areas, it is found that, in the five years under consideration, 737 storms of various points of origin entered the United States and the British possessions. Of this number, 449, or over 60 per cent., moved to within 1,000 miles of Baltimore, and for every two of these that had their origin in the Gulf, in the southeast or over the Southern Plateau, five moved in from the northwest. Within the next 300 miles, the total had been reduced to 328,

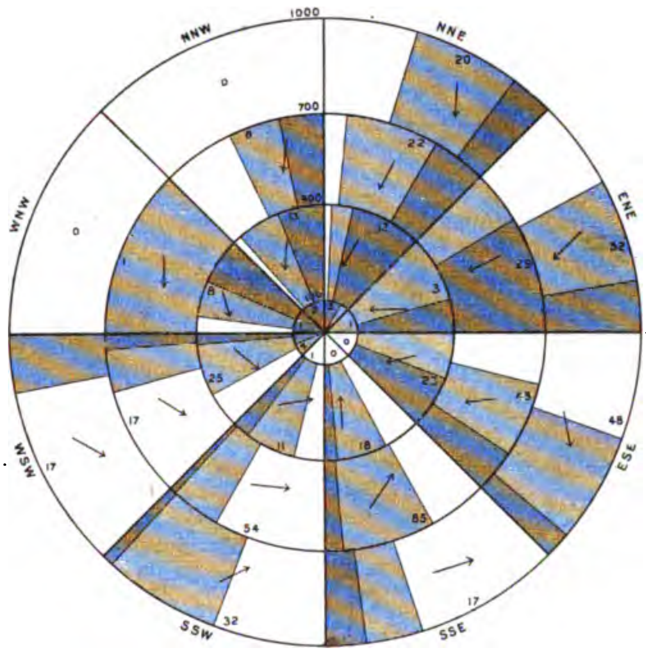

FIG. 35.—Hypothetical cyclonic area showing weather conditions when Baltimore is covered by the given tract during December–February.[1]

or a loss of 91 northwest and 30 Gulf storms. Within the 400-700 mile limit, the number had increased by 64; the main reason for this increase is due to the fact that the pressure system centers were located for regular twelve-hour periods, 8 A. M. and 8 P. M., and very fre-

[1] Unshaded portion shows percentage of clear; the entire shading, percentage of cloudiness; and the heavier shading, the percentage of rain. Arrows show resultant winds. Numerals give the number of observations upon which the results are based.

quently the rapid movement of the areas carried their centers from outside the 1,000 mile limit entirely across the intervening belt into the 400-700 mile limit in less than twelve hours, and, consequently, while the storm during its passage had been in the outer district, such location was necessarily ignored in the plan upon which the tables were based; minor reasons for the increase are also found in the birth of storms within the interior area. Again, other storms formed in the southeast, and, while they doubtless existed in the larger southeastern tracts, could not be located at the time of their formation far out in the ocean beyond the limits of observation. Coming to the area of 100-400 miles, there are left 192 storms, or something over 40 per cent. of those originally appearing within the 1,000 mile limit. And within 100 miles, only 30 storms have centered in the past five years.

There is a moderately well-defined distribution of cyclonic storms throughout the year as regards frequency. This is most apparent in those of the Gulf origin. It is not needful to account for those outside of the 400-700 mile limit. Within the latter area, storms of all origin are most frequent in November to March and in August, and least frequent in May and September; and within the 100-400 mile limit they are most frequent in January, February and March. As to place of origin: For 400-700 miles, the northwest storms are of most frequent occurrence in February, March, August and November, and least in May, June and September, while the more active periods of storms of Gulf formation are very plainly marked in winter months from December to March inclusive. Within the 100-400 mile limit, the northwest storms have their minimum frequency in June, September, October and December; but the Gulf storms, as before, continue with much greater frequency from December to March than in the other months.

Of the anticyclonic areas, 522 in all, or about two to every three of cyclonic formation that have entered the United States in the past five years, only 124 failed to penetrate the 1,000 mile limit of Baltimore. These areas have not been considered with regard to origin, as they mainly appear in the far northwest or over the middle Pacific

coast. Within the next 300 miles toward Baltimore, the number was reduced to 279, or, in other words, every third or fourth anticyclone either passed outside, usually to the northward, of the circular land area confined within the 700 mile limit of Baltimore, or else lost its distinguishing features of anticyclonic formation. Within the next approach of 300 miles, only 44 failed to appear, and exactly 44 were again missing with the next stage of progress to within 100 miles. By this time, however, the area of the pathway taken by the

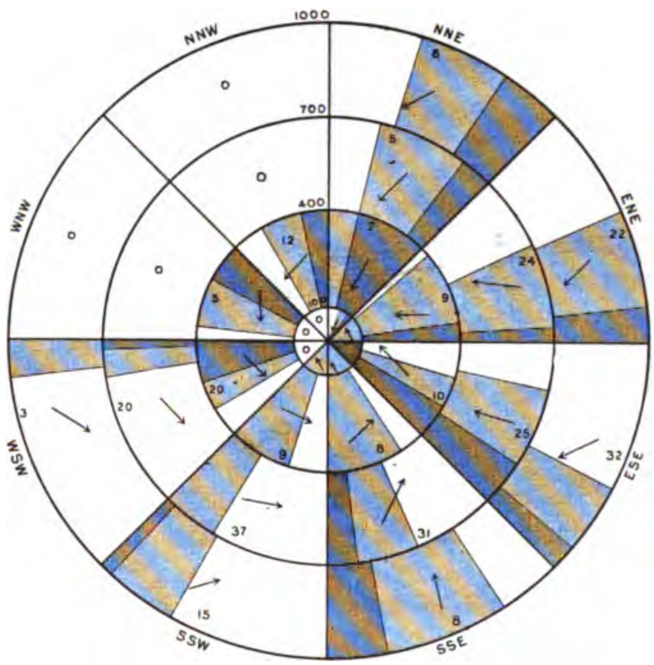

FIG. 36.—Hypothetical cyclonic area showing weather conditions when Baltimore is covered by the given tract during March–April.

anticyclones in their usual course toward the Atlantic is enlarged, as compared with the narrowing diameter of 200 miles around Baltimore; and, of the 211 anticyclones still to be considered, the center of only 23 passed within 100 miles of Baltimore.

As to frequency by months, only those coming within 700 miles need to be considered. Of these, for the 400-700 mile limit, the distribution is not marked in a pronounced way. May and July

show the least, and April, September and October the greatest frequency. Within the 100-400 mile limit, March, September, October and November lead in the number of anticyclones, and July and December have the least. Within the 100 mile limit, 5 of the 23 anticyclonic centers passed through in March, and the next greatest number, 4, in June.

In the preparation of the figures and tables, no distinguishing reference could well be made to the intensity of these cyclonic and anticyclonic areas. The intensity of a pressure area modifies its direction of movement to some extent and otherwise determines the character of the weather associated with its movements, but it is hardly probable that these facts could be made apparent in an averaging of conditions as given in the tables. This feature will be discussed in a limited way under the heading of Weather Types, pp. 449-460. The general path of storms, also an important point, has been given in publications of the U. S. Weather Bureau, and as the figures there furnished are well established for a longer period than is here considered, no attempt has been made to cover the same ground in the local study. Reference has already been made to these main storm tracks.

It now becomes necessary to discuss the plotted cyclonic and anticyclonic conditions, as shown in the figures and tables. For a better understanding, a tract will be designated by one of the numbers 1, 4, 7 or 10, according to whether it is enclosed on its outer margin by the circle whose circumference is 100, 400, 700 or 1,000 miles from the storm center, and the several octants will be referred to as NNE, WSW, etc.; thus, NNE-4 would mean the tract lying north-northeast of the pressure area center at a distance of 100 to 400 miles. It must be remembered that, in the immediate summary, the point of reference is not Baltimore, but a hypothetical cyclonic or anticyclonic center, so situated that Baltimore is covered by some one of the tracts as above named. These will be discussed in sequence from the original figures.

THE GULF STORMS.

These include all storms forming south of the 40th parallel. They are more prevalent during the winter season than at any other time.

NNE Octant.—When tract 10 includes Baltimore during December to February inclusive, there is found, for the past five years, an average condition of 59 per cent. cloudiness, and 18 per cent. of rain actually falling; the resultant winds are west of north. As tract 7 covers Baltimore, the cloudiness increases to 79 per cent., rainy conditions to 26 per cent., and the winds become east of north. As tract 4 approaches and embraces Baltimore, cloudiness increases to total and rainfall to 62 per cent., while resultant winds are from the

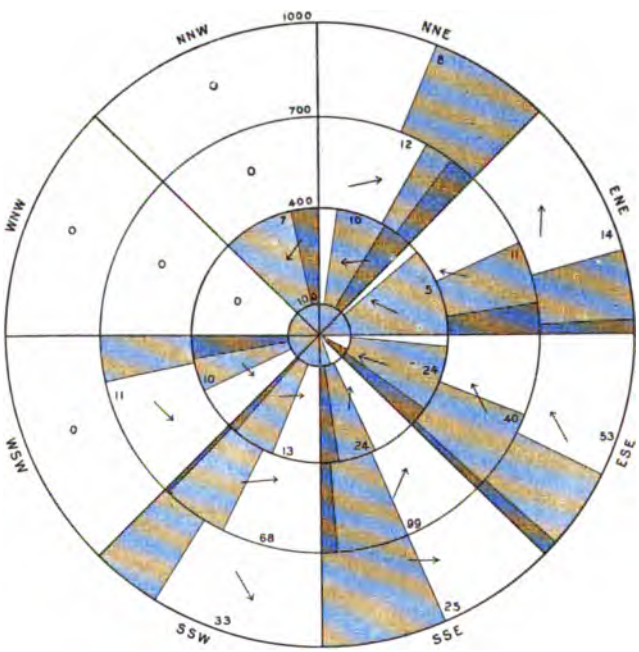

Fig. 37.—Hypothetical cyclonic area showing weather conditions when Baltimore is covered by the given tract during May–August.

northeast; conditions do not materially change with Baltimore in the same octant and within 100 miles of the storm center.

In March and April the actual number of storms is considerably lessened. There is more rain and cloudiness in tract 10, but the resultant winds are about the same; the other tracts do not differ materially for rain and clouds.

From May to August these storms are still few in number. Rain has disappeared entirely in tract 10 and has been reduced in the other tracts, as also cloudiness. Resultant winds are very different, however, in tracts 10 and 7, now blowing from a southerly direction, but in tract 4 they continue from the northeast with a tendency to easterly.

In the fall months the number of storms increases, but there is not much change in rainy and cloudy conditions. The winds, however, shift again to northeast in all tracts.

ENE Octant.—In tract 10 for winter the cloudiness is 85 per cent. and rain actually falling 33 per cent., with resultant winds northeast. In tract 7, during the same season, the rainy conditions reach a maximum 70 per cent., giving the most marked rainy period of all that were plotted; winds tend to easterly with the approach of the storm center to Baltimore. As spring approaches, the number of times that Baltimore is influenced by this part of the circulation diminishes, and conditions become less favorable for rain and cloudiness; resultant winds are still easterly. In summer and fall the liability of Baltimore to be within this part of the circulation is further lessened; rain disappears in tract 10; it has a slight increase over spring in tract 7, but the cloudiness has a decided decrease; winds tend to southerly.

ESE Octant.—Easterly winds and complete cloudiness prevail in tract 10 throughout the year, with about 20 per cent. of rain actually falling in winter, 50 per cent. in spring, and none in summer and fall. The rainy conditions increase as Baltimore is within tract 7 during winter, but rain entirely disappears in the other seasons.

SSE Octant.—Tract 10 presents no data for Baltimore. Tract 7 shows from 8 per cent. of rain in winter to 20 per cent. in summer. Winds are south to southwest for all tracts and months, and 50 per cent. to 75 per cent. of cloudiness prevails at various times, being greatest in spring.

SSW Octant.—Tract 10 shows no rain at all; half cloudiness prevails in the winter months, decreasing to about 20 per cent. in spring and increasing to about 50 per cent. in summer and 60 per cent. in

fall; winds are southwest in winter, spring and fall, and northwest in summer. In tract 7 there is no rain, with 35 per cent. cloudiness in winter, becoming 10 per cent. in spring, entirely clear in summer and 20 per cent. in fall; winds are westerly throughout the year. Tract 4 is one-third rainy in winter, but has no rain actually falling in spring; there is no recorded entry of Baltimore being in this tract

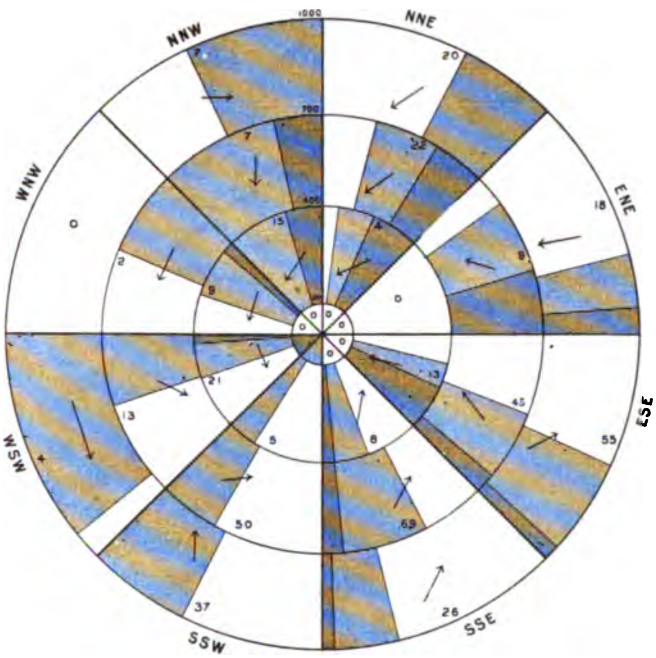

Fig. 38.—Hypothetical cyclonic area showing weather conditions when Baltimore is covered by the given tract during September–November.

in summer and fall; winds are south of west in winter, north of west in spring.

WSW Octant.—In tract 10 there is no plotted entry for spring and summer; for the other seasons there is 25 per cent. of cloudiness in winter, and 88 per cent. in fall, but no rain. Tract 7 has no rain, and the amount of cloudiness for the different seasons ranges from 10 per cent. in spring to 40 per cent. in fall; no rain falls in tract 4 in winter, although 60 per cent. of cloudiness prevails. Spring has 50

per cent. of rain and 75 per cent. of cloudiness; summer has the same percentage of rain and complete cloudiness. In fall there is 30 per cent. of cloudiness and no rain. Winds are northwest for all tracts and all seasons.

WNW OCTANT.—The number of times Baltimore has been included in the circulation of tract 10 is not determinable, and only two times are recorded for tract 7. For tract 4 there is 50 per cent. of rain and 88 per cent. of cloudiness for the winter months; spring and summer present but one observation each; fall gives 20 per cent. of rain and 70 per cent. cloudiness. Winds are generally northeast in fall and northwest during the other seasons in all tracts.

NNW OCTANT.—With Baltimore under tract 10 the only observed storms are in the fall, probably West India hurricanes; for that season there is no rain at hours of observation, 57 per cent. of cloudiness, and westerly winds. Tract 7 has no observations for spring and summer; in the fall there is complete cloudiness and 35 per cent. of rain; in winter half cloudiness and 29 per cent. rain; winds north to northeast. In the case of tract 4, winds are northeast throughout; in winter 60 per cent. of rain and complete cloudiness, in spring 46 per cent. rain and 86 per cent. cloudiness, in summer 33 per cent. rain and complete cloudiness, and in fall 43 per cent. rain and 93 per cent. cloudiness.

NORTHWEST STORMS.

NNE OCTANT.—With tract 10 over Baltimore there is 67 per cent. of cloudiness and no rain in winter; entirely clear in spring; no observations for summer and only one for fall; winds north to northeast. Tract 7 in winter gives 43 per cent. of rain actually falling, and complete cloudiness; in spring one-half cloudiness but no rain; in summer entirely clear; in the fall 67 per cent. for rain, and complete cloudiness; winds for all seasons are northeast. Tract 4 in winter gives three-fourths and in spring one-half rain and cloudiness; in summer, half cloudiness and no rain; there are no observations for fall; winds are northeast throughout.

ENE OCTANT.—When Baltimore lies under tract 10 there is an average of 16 per cent. of rain actually falling in winter, 50 per

cent. in summer, 11 per cent. in fall, and none in spring; the cloudiness is one-fourth in spring and fall, one-half in winter and three-fourths in summer; the winds are northeast, except in the summer months when they are south. For tract 7, in the winter months there is complete cloudiness, and 67 per cent. of rain actually falling, a frequency second only to the Gulf storm periods for the same tract; in other seasons the rain ranges from 7 per cent. to 17 per cent.; in the spring months the cloudiness decreases to 40 per cent., but

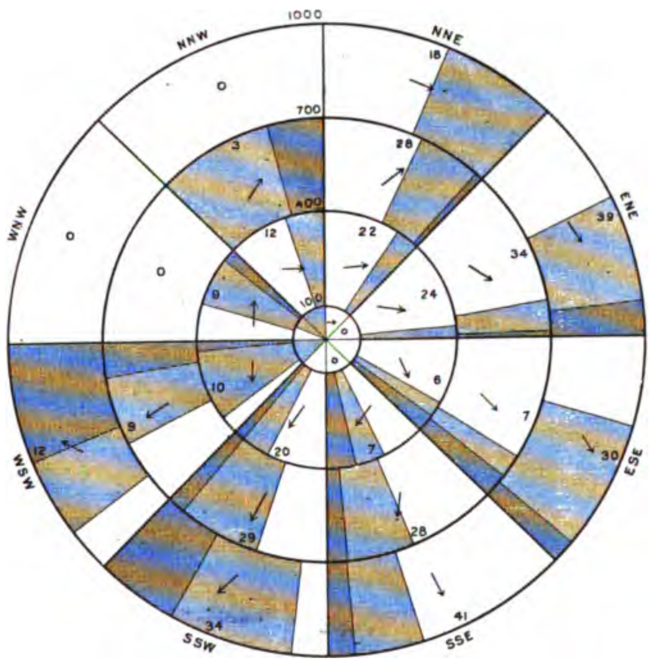

FIG. 39.—Hypothetical anticyclonic area showing weather conditions when Baltimore is covered by the given tract during November–March.

increases in summer to 67 per cent.; the resultant winds are northeast for winter, east for spring and summer, and southeast for fall. Tract 4 gives 12 per cent. of rain in spring, and none in other seasons; cloudiness is complete, however, for all the months; the winds are easterly in the fall and spring, southeasterly in summer, and northwesterly in winter.

ESE Octant.—With Baltimore at tract 10 there is 6 per cent. rain actually falling in fall and 10 per cent. in other months; about half cloudiness prevails throughout the year; the resultant winds are east-northeast in winter, and southeast in other months. Tract 7 gives 32 per cent. rain in spring and less than half as much at other times; cloudiness ranges throughout the year from 50 per cent. to 68 per cent., being greatest in spring; the resultant winds are nearly east in winter, changing as the year advances to nearly due southeast in summer and fall. Tract 4 has about 50 per cent. of rain in winter and fall, and half as much in spring and summer; cloudiness is large, ranging from 58 per cent. in spring to completely overcast in winter; the resultant winds are different for each of the seasons—northwest in winter, northeast in spring, southeast in summer, and southwest in fall.

SSE Octant.—For tract 10 there is 18 per cent. of rain in winter, 25 per cent. in spring, none in summer, and extremely light in fall; cloudiness is greatest in spring, 75 per cent., with half cloudy in summer, and least, 31 per cent., in fall; resultant winds are southwest in winter and fall, west in summer, and southeast in spring. There is a very small percentage of rain actually falling from tract 7, that of spring, 18 per cent., being the greatest; cloudiness ranges from 50 per cent. to 60 per cent. throughout the seasons; resultant winds are southwest for all months. Tract 4 gives no rain in spring and from 14 per cent. to 19 per cent. in other seasons; cloudiness ranges with a gradual decrease from 71 per cent. in winter to half cloudy in fall; the resultant winds are southwest in spring and south in the other months.

SSW Octant.—Tract 10 gives about 10 per cent. of rain in winter and spring, and none in the other months; half cloudiness prevails in the same seasons but is less in summer and fall; resultant winds are south in fall, becoming southwest in winter and spring, and northwest in summer. For tract 7 rain actually falls very few times in winter and summer, and not at all in spring and fall; cloudiness varies from 35 per cent. to 45 per cent. for all seasons; resultant winds are nearly due west in winter and spring, becoming more southwest in

summer. For tract 4, the percentage of rain is light for winter and summer, with none in the other months; cloudiness is 68 per cent. in winter, gradually decreasing to 30 per cent. in fall; resultant winds are west-southwest in winter, northwest in spring, west in summer, and southwest in fall.

WSW Octant.—There are no observations for tract 10 in summer and fall, and no rain actually fell at hours of observation in the other

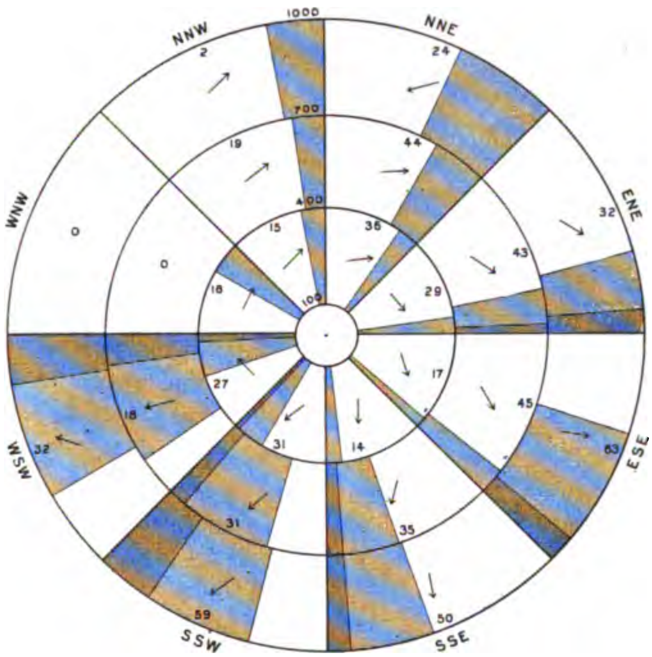

Fig. 40.—Hypothetical anticyclonic area showing weather conditions when Baltimore is covered by the given tract during April–October.

seasons; scant cloudiness prevails in winter and spring. Tract 7 causes 17 per cent. of rain in winter, 10 per cent. in spring, and none in the other months; cloudiness is 62 per cent. in fall and about 35 per cent. in the other seasons. Tract 4 gives 20 per cent. to 25 per cent. of rain actually falling in winter and spring and half as much in summer and fall; cloudiness is 43 per cent. in summer and above 60 per cent. at other times; resultant winds are northwest for all tracts and seasons.

WNW OCTANT.—No observations appear for tracts 10 and 7. Tract 4 has four observations for summer, and only one for the winter months; for spring there is 25 per cent. of rain and 97 per cent. of cloudiness; in the fall months there is 50 per cent. of cloudiness and no rain; resultant winds are from the north.

NNW OCTANT.—There are no observations recorded except for tract 4. This gives 25 per cent. of rain for the summer months, and none in other seasons. There is 68 per cent. of cloudiness in winter, 40 per cent. in spring, completely overcast in summer, and none in fall; the winds are north in the winter, and northeast for the other months.

This completes a brief review of the conditions shown in the original plottings of the cyclonic areas. As the two classes of storms have been combined in the cyclonic figures given in this volume, the preceding summary will not at all times exactly agree with these charted conditions.

No extended discussion will be given of the anticyclonic figures. It may be stated in a general way, however, that the rainfall in an anticyclonic area is confined almost entirely to the southern half of the circulation; it is greatest in the outermost tracts and decreases with approach to the center. The largest percentage of clear weather conditions is found in the eastern and northeastern tracts of the anticyclones, while the cloudiness lies mostly in the western tracts. The resultant winds are given in the figures 39-40, and other general conditions are there equally apparent.

TABLES FOR CYCLONIC OR STORM AREAS.

Thus far in the study of precipitation, account has been taken only of the times when rain was *actually falling* at Baltimore, when that city was in a given direction and at a definite distance from the pressure area center; such being the nature of the data given for precipitation in the shaded figures. It will also be understood that the word rain is always used in a general sense, including all forms of precipitation, whether rain, hail, sleet or snow.

The tables now demand attention. They show, for Gulf storms, northwest storms and anticyclones, the percentage of times that

CYCLONIC FORMATION FOLLOWED BY PRECIPITATION AT BALTIMORE, MD.

December–January–February.

Octant.	Origin of cyclonic area.	Tract 10. No. observed.	Tract 10. Percentage of times followed by rain in 12 hrs.	24 hrs.	36 hrs.	48 hrs.	Tract 7. No. observed.	Tract 7. Percentage of times followed by rain in 12 hrs.	24 hrs.	36 hrs.	48 hrs.	Tract 4. No. observed.	Tract 4. Percentage of times followed by rain in 12 hrs.	24 hrs.	36 hrs.	48 hrs.
			%	%	%	%		%	%	%	%		%	%	%	%
NNE.	Northwest ..	3	33	0	0	0	7	71	0	0	0	4	75	0	0	0
	Gulf	17	53	35	0	6	15	47	13	0	0	8	88	0	0	0
ENE.	Northwest ..	19	41	21	0	0	9	100	0	0	0	1	100	0	0	0
	Gulf	33	54	21	6	0	20	100	0	0	0	2	100	0	0	0
ESE.	Northwest ..	41	17	12	10	2	31	6	23	3	0	8	87	0	0	0
	Gulf	7	70	16	14	0	17	53	5	0	0	15	80	0	0	0
SSE.	Northwest ..	17	18	0	0	0	73	25	7	3	1	14	36	14	7	0
	Gulf	0	..	..	..	..	12	25	17	8	0	4	50	0	25	0
SSW.	Northwest ..	0	..	..	..	..	0	..	..	..	..	8	12	0	0	0
	Gulf	0	..	..	..	..	0	..	..	..	..	3	67	0	0	0
WSW.	Northwest ..	0	..	..	..	..	0	..	..	..	..	8	25	0	..	..
	Gulf	0	..	..	..	..	0	..	..	..	..	3	33	33	..	..
WNW.	Northwest .	0	..	..	..	..	0	..	..	..	..	1	0	0	..	..
	Gulf	0	..	..	..	..	0	..	..	..	..	8	62	25	..	..
NNW.	Northwest .	0	..	..	..	..	0	..	..	..	..	0	..	..	..	..
	Gulf	0	..	..	..	..	7	43	14	0	14	10	80	0	10	10

Tract 1.—All storms and octants. 9 storms, all followed by rain in 12 hours.

March–April.

Octant.	Origin of cyclonic area.	Tract 10. No. observed.	Tract 10. 12 hrs.	24 hrs.	36 hrs.	48 hrs.	Tract 7. No. observed.	Tract 7. 12 hrs.	24 hrs.	36 hrs.	48 hrs.	Tract 4. No. observed.	Tract 4. 12 hrs.	24 hrs.	36 hrs.	48 hrs.
NNE.	Northwest ..	3	0	0	0	0	2	50	50	0	0	2	100	0	0	0
	Gulf	5	0	40	0	0	3	33	0	0	0	5	80	0	20	0
ENE.	Northwest ..	12	17	59	8	8	14	36	14	0	0	9	100	0	0	0
	Gulf	10	30	40	10	0	10	90	10	0	0	1	100	0	0	0
ESE.	Northwest ..	30	27	13	23	13	22	73	14	14	0	8	50	12	0	0
	Gulf	2	50	50	0	0	3	100	0	0	0	2	50	0	0	0
SSE.	Northwest ..	8	62	12	0	0	32	37	19	3	0	6	23	0	0	0
	Gulf	0	..	..	..	..	5	100	0	0	0	2	50	0	0	0
SSW.	Northwest ..	0	..	..	..	..	0	..	..	..	..	0	..	..	..	..
	Gulf	0	..	..	..	..	0	..	..	..	..	0	..	..	..	..
WSW.	Northwest ..	0	..	..	..	..	0	..	..	..	..	0	..	..	..	..
	Gulf	0	..	..	..	..	0	..	..	..	..	0	..	..	..	..
WNW.	Northwest ..	0	..	..	..	..	0	..	..	..	..	4	50	0	0	0
	Gulf	0	..	..	..	..	0	..	..	..	..	2	100	0	0	0
NNW.	Northwest ..	0	..	..	..	..	1	100	0	0	0	5	20	0	0	0
	Gulf	0	..	..	..	..	0	..	..	..	..	7	57	14	0	0

Tract 1.—All storms and octants. 7 storms, 71% followed by rain within 12 hours.

CYCLONIC FORMATION FOLLOWED BY PRECIPITATION AT BALTIMORE, MD.—*Continued.*

MAY TO AUGUST, INCLUSIVE.

Octant.	Origin of cyclonic area.	Tract 10. No. observed.	Tract 10. Percentage of times followed by rain in 12 hrs.	24 hrs.	36 hrs.	48 hrs.	Tract 7. No. observed.	Tract 7. Percentage of times followed by rain in 12 hrs.	24 hrs.	36 hrs.	48 hrs.	Tract 4. No. observed.	Tract 4. Percentage of times followed by rain in 12 hrs.	24 hrs.	36 hrs.	48 hrs.
			%	%	%	%		%	%	%	%		%	%	%	%
NNE.	Northwest ..	1	100	0	0	0	1	100	0	0	0	2	100	0	0	0
	Gulf	8	50	12	12	0	10	33	0	0	0	8	75	12	0	12
ENE.	Northwest ..	2	50	50	0	0	7	43	29	29	0	3	67	33	0	0
	Gulf	12	25	8	8	0	4	50	25	0	0	2	100	0	0	0
ESE.	Northwest ..	47	25	30	19	2	27	20	7	3	0	11	100	0	0	0
	Gulf	6	17	0	0	0	13	0	0	0	0	3	33	0	0	0
SSE.	Northwest ..	25	24	24	8	0	94	31	11	4	2	21	67	9	0	0
	Gulf	0	..	..	..	..	5	40	0	20	0	3	0	0	0	0
SSW.	Northwest ..	30	0	33	0	0	61	6	0	0	0	13	46	0	0	0
	Gulf	3	0	0	0	0	7	0	0	0	0	0	..	..	..	..
WSW.	Northwest ..	0	..	..	..	..	0	..	..	..	..	8	50	12	0	0
	Gulf	0	..	..	..	..	0	..	..	..	..	2	50	0	0	0
WNW.	Northwest ..	0	..	..	..	..	0	..	..	..	..	0	..	..	..	..
	Gulf	0	..	..	..	..	0	..	..	..	..	1	100	0	0	0
NNW.	Northwest ..	0	.	..	..	..	0	..	..	..	..	4	100	0	0	0
	Gulf	0	..	.	..	..	0	..	..	..	..	3	67	0	0	0

TRACT 1.—All storms and all octants. 14 storms, 64% followed by rain within 12 hours.

SEPTEMBER–OCTOBER–NOVEMBER.

Octant.	Origin of cyclonic area.	Tract 10. No. observed.	Tract 10. 12 hrs.	24 hrs.	36 hrs.	48 hrs.	Tract 7. No. observed.	Tract 7. 12 hrs.	24 hrs.	36 hrs.	48 hrs.	Tract 4. No. observed.	Tract 4. 12 hrs.	24 hrs.	36 hrs.	48 hrs.
NNE.	Northwest ..	1	100	0	0	0	3	100	0	0	0	0	0	0	0	0
	Gulf	19	47	10	16	5	19	47	10	0	0	4	100	0	0	0
ENE.	Northwest	9	22	0	41	11	4	100	0	0	0	1	100	0	0	0
	Gulf	9	22	22	33	11	5	60	0	0	0	0	..	..	..	..
ESE.	Northwest ..	54	22	26	17	0	41	34	22	5	0	11	45	36	0	0
	Gulf	1	100	0	0	0	4	100	0	0	0	2	0	0	0	0
SSE.	Northwest ..	26	12	12	8	4	63	32	11	2	5	6	80	0	0	0
	Gulf	0	.		..	.	6	17	0	0	0	2	0	0	0	0
SSW.	Northwest ..	0	..	.		..	0		..	..	..	0	..	..	..	.
	Gulf	0	..	..	..	.	0	.	..	..	..	0	..	..	..	..
WSW.	Northwest ..	0	.	..	.	.	0			..	..	0	..	..	..	..
	Gulf	0	..	..	..		0		..	..	..	0	..	..	..	..
WNW.	Northwest ..	0	.	.	..		0		..	..	..	4	25	0	0	0
	Gulf	0	..	..	..		2	50	0	0	0	5	20	0	0	0
NNW.	Northwest ..	0	.	.	..		1	0	0	0	0	1	0	0	0	0
	Gulf	7	43	29	14	0	6	33	17	0	0	14	71	7	0	0

TRACT 1.—All storms and all octants. 4 storms, all followed by rain within 12 hours.

rainfall occurred within the 12, 24, 36 and 48 hour period following the location of Baltimore in a given tract, and have no reference to whether rain was actually falling at 8 A. M. and 8 P. M., the hours of synoptic charting. As an aid to weather forecasting, the value of these tables, as a whole, may be questionable. But the fact is disclosed that, under certain conditions, the relations between Baltimore and the pressure area centers with respect to distance and direction are followed to such a marked degree by similar weather elements as to render their value manifest, and when, hereafter, a chart is found with Baltimore and the pressure area centers having similarly related positions, the conclusion is unavoidable that the almost unvarying weather conditions that have been found to follow in the past will again occur.

While all percentages obtainable for the five years' study are given in the tables, some are decidedly lacking in value through the infrequent occurrence of the conditions upon which they are based. In the deductions that follow only those conditions that are based on a fairly large number of observations will be considered. A short review of the twelve-hour period is given, with reference to the location of these storm centers in stated geographical areas:

THE 400-MILE LIMIT.—Of all storms located within this limit, those centered to the north-northeast or east-northeast have already expended their rain-producing effects, and dry weather generally, though not always, prevails during the ensuing 12 hours. Of those passing over Lake Erie and Lake Ontario, about one-half are followed by rain in spring and fall, and nearly all in winter and summer. For the other tracts within the 400-mile limit, the storms of all seasons cause rainfall within 12 hours about nine times out of every ten.

OHIO VALLEY AND TENNESSEE.—In the winter months a storm of any origin centering in the Ohio valley or Tennessee has, during the past five years, invariably caused rain at Baltimore within twelve hours. In the spring the Gulf storms continue very largely rain-producing, but those from the northwest do not generally cause rain. In the summer about one-half of all the storms are followed by rain; and in fall, all from the northwest, and about 60 per cent. of those from the Gulf, cause rain within twelve hours.

VICINITY OF LAKE MICHIGAN.—None of the summer Gulf storms produce rain in twelve hours, while about one-half of those in winter, and all in spring and fall are followed by rain. There is very little likelihood of rain in twelve hours from the northwest storms except in spring, when three out of four cause precipitation.

SOUTH ATLANTIC STATES.—With storms of northwest origin, all in fall, 75 per cent. in winter, and 50 per cent. in spring, are followed by rain in twelve hours; in summer only one northwest storm has moved into this region in the past five years, and it was followed by rain in twelve hours. Of the Gulf storms, about one-half produce rain in twelve hours in fall and winter, and less than 40 per cent. in spring and summer; out of eighteen Gulf storms in this section in May, June, July and August in the past five years, only seven have been followed by rainfall in twelve to forty-eight hours.

UPPER MISSISSIPPI VALLEY.—In winter, with a storm of Gulf origin centered in the upper Mississippi valley, rain follows in twelve hours five times out of seven; but with a storm from the northwest, only one time in six. The probability of rain from a Gulf storm decreases in the remaining seasons, and for a northwest storm increases to about one in every four.

LOWER MISSISSIPPI VALLEY.—About 40 per cent. of the northwest storms produce rain in twelve hours in winter, with probability growing less for other months. The same varying rate of probability prevails for the Gulf storms, except that it is slightly higher, ranging from 54 per cent. in winter to the lowest, 22 per cent., in fall.

For all storms, irrespective of origin or location, it is noticed, in this five years' study, that whenever the storm tends to move toward Baltimore, with its center passing successively from one tract to another in the *same octant*, rain invariably follows within 12 to 24 hours.

Following this general plan, studies may be made for the 24, 36 and 48 hour periods. The limits of this article preclude other than this brief reference.

TABLES FOR ANTICYCLONES.

The anticyclonic tables have been compiled into divisions of winter and summer conditions, and show the number of times that rainfall

began within 24 and 48 hours following the location of Baltimore in any of the given tracts. A few of the facts obtainable from these tables are as follows:

In the past five years, 23 areas of high pressure have centered within 100 miles of Baltimore as already stated; of these, two were followed by rain in 24 hours and eight by rain in 48 hours.

About three high areas form in summer to two in winter along the south Atlantic coast.

The probability of the commencement of rainfall within twenty-four hours increases with the distance of the center of high pressure from Baltimore. Probability of rainfall in 48 hours, however, is greater when the center of high pressure is between 100 and 400 miles of Baltimore than at any other distance; the percentages of probability as observed in the past five years for the 100, 400, 700 and 1,000 mile limits are 9, 32, 18 and 13 per cent. respectively.

With an anticyclonic area centered to the north-northeast or east-northeast, rain occurs within 24 hours at Baltimore more frequently than when the area lies in any other direction. With such location at a distance of 700 to 1,000 miles, rain follows 85 per cent. of times in winter and 60 per cent. in summer. This probability follows the general rule of decrease as the center approaches Baltimore, being reduced to 61 per cent., either winter or summer, for a distance of 400 to 700 miles, and to 45 per cent. in winter and 20 per cent. in summer for a distance of 100 to 400 miles.

With high pressure areas located south-southwest of Baltimore at a distance of 700 to 1,000 miles, about one-half are followed by rain in 24 hours, while at a distance of 400 to 700 miles the probability is about 30 per cent., and at 100 to 400 miles it is reduced to 8 per cent.

Anticyclonic areas located west-southwest of Baltimore at a distance of 700 to 1,000 miles are followed 65 per cent. of times by rainfall in 24 hours in summer and 46 per cent. of times in winter.

The only remaining position of the anticyclonic areas followed by rainfall in 24 hours worthy of special notice is west-northwest at a distance of 700 to 1,000 miles from Baltimore, when in summer 63

per cent., and in winter 57 per cent. of those so located are followed by rain within 24 hours.

As earlier stated, these deductions have an uncertain value. But they are, at least, actual facts as obtained from a study of conditions that have prevailed during the past five years. The connection between certain locations of the pressure area systems and the

ANTI-CYCLONIC FORMATION FOLLOWED BY PRECIPITATION AT BALTIMORE.

WINTER CONDITIONS:—NOVEMBER–MARCH.

	Tract 10.			Tract 7.			Tract 4.			Tract 1.		
	No. observed.	Percentage of times followed by rain in		No. observed.	Percentage of times followed by rain in		No. observed.	Percentage of times followed by rain in		No. observed.	Percentage of times followed by rain in	
		24 hours.	48 hours		24 hours.	48 hours.		24 hours.	48 hours.		24 hours.	48 hours.
		%	%		%	%		%	%		%	%
NNE.........	18	56	17	28	25	36	22	5	41	2	50	50
ENE.........	39	46	18	34	24	18	26	15	27	0	..	..
ESE.........	30	57	10	7	57	0	6	50	34	2	0	50
SSE.........	41	34	24	28	39	39	7	71	14	0	..	..
SSW.........	34	85	9	29	66	10	20	45	25	1	0	0
WSW.........	12	100	0	9	44	11	10	70	40	1	0	0
WNW.........	0	...	..	0	..	..	9	22	33	3	0	33
NNW.........	0	...	..	3	67	0	12	25	42	1	0	0

SUMMER CONDITIONS:—APRIL–OCTOBER.

NNE.........	24	50	17	44	36	18	36	11	30	3	0	67
ENE.........	32	66	6	43	40	7	29	0	33	2	50	0
ESE.........	63	63	10	45	29	13	17	18	18	1	0	0
SSE.........	50	52	14	35	31	20	14	21	42	1	0	0
SSW.........	59	61	15	31	58	16	31	19	29	1	0	0
WSW.........	32	78	9	18	44	22	27	33	26	0	..	..
WNW.........	0	..	..	10	0	0	18	11	44	1	0	0
NNW.........	2	100	0	19	42	21	15	33	33	4	0	50

weather elements coincident or following, that have been brought out in these studies does not necessarily argue cause and effect, especially in those discussions where the anticyclones have been connected with the positive production of rain. Still it is possible, and in pronounced cases probable, that these deductions, combined with a general knowledge of the laws of cyclonic and anticyclonic formation and movement, will be found of service in the forecasting of weather.

Other interesting studies of weather are possible along the lines here followed for rainfall, cloudiness and resultant winds. It is hoped at some later date to consider the very important subject of temperature change and wind force attending the formation and movement of the pressure areas. This subject has already been given some attention by Professor E. B. Garriott, of the U. S. Weather Bureau. Professor Garriott has combined the results of his observation in a wind-barometer table, which originally appeared in the Monthly Weather Review, and is here reproduced. It presents, in form for ready reference, atmospheric signs which have been found to presage certain weather changes and conditions over the middle and upper Mississippi and lower Missouri valleys, the Great Lakes, the Ohio valley, and the middle Atlantic and New England states:

WIND-BAROMETER TABLE.

Barometer (reduced to sea level).	Wind direction.	Character of weather indicated.
30.00 to 30.20, and steady	Westerly	Fair, with slight changes in temperature, for one to two days.
30.00 to 30.20, and rising rapidly	Westerly	Fair, followed within two days by warmer and rain.
30.00 to 30.20, and falling rapidly	S. to E.	Warmer, and rain within 24 hours.
30.20, or above, and falling rapidly	S. to E.	Warmer, and rain within 36 hours.
30.20, or above, and falling rapidly	W. to N.	Cold and clear, quickly followed by warmer and rain.
30.20, or above, and steady	Variable	No early change.
30.00, or below, and falling slowly	S. to E.	Rain within 18 hours that will continue a day or two.
30.00, or below, and falling rapidly	SE. to NE.	Rain, with high wind, followed within two days by clearing, colder.
30.00, or below, and rising	S. to W.	Clearing and colder within 12 hours.
29.80, or below, and falling rapidly	SE. to NE.	Severe storm of wind and rain imminent. In winter snow and cold wave within 24 hours.
29.80, or below, and falling rapidly	E. to N.	Severe northeast gales and heavy rain or snow, followed in winter by cold wave.
29.80, or below, and falling rapidly	Going to W.	Clearing and colder.

Weather Types.

Despite the seeming inconsistencies of the weather and the extreme irregularity of its changes, there are certain types of high and low areas of pressure which, in their relative arrangement, formation and movement are frequently repeated and produce, each time they occur, weather of a similar character. A description of some of the more prominent typical forms, and the respective paths of the attend-

ant cyclonic and anticyclonic systems, is here given. With each of these systems is associated a distinct sequence of weather phenomena. In considering these types, the positions and paths of the cyclonic and anticyclonic areas, with relation to each other, must be taken into account.

It might be well to state in advance that any arrangement of the high and low pressure areas which would cause a drift of air from land to sea tends to bring fair weather, while any arrangement that would cause a drift of air from sea to land would result in increasing cloudiness and tendency to rain. Therefore, for this state, the rain-producing winds are from northeast to south, and the dry winds from southwest to northwest.

The arrangement of pressure areas most favorable for rain is, a low area over Georgia, Tennessee or the Ohio valley, and a high near the Gulf of St. Lawrence; while the reverse of this arrangement is least favorable and tends to produce clear and dry weather.

CANADIAN TYPE.

The passage of a northwest storm, or cyclonic area, along the main northern track to the Gulf of St. Lawrence, closely followed by an area of high pressure which passes off over the Middle Atlantic states, is a very common type, especially in the summer months. When it occurs in the spring it gives the cool waves and damaging late frosts of that season. Clear weather usually attends this type. As the center of the low approaches the upper Lake region the winds become southerly and the temperature rises. But by the time the cyclonic area reaches the North Atlantic coast, the high has moved to the Lake region and Ohio valley, the winds shift to northwesterly and the temperature begins to fall. As the high area settles over this section the winds decrease in force; the air is entirely clear, and there is rapid terrestrial radiation—conditions most favorable for frost formation. This type is illustrated in Figure 41, which is a reproduction of the 8 A. M. weather map of April 20, 1897.

LAKE TYPE.

This is similar to the former in origin, but its track is much farther south. Its first movement is southeastward to Iowa, where it turns

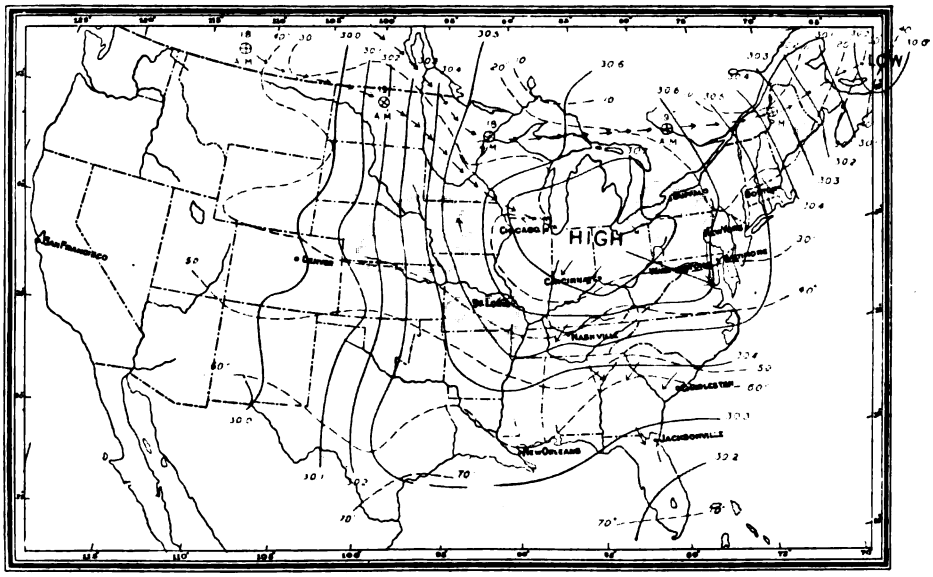

FIG. 41.—Canadian type, April 20, 1897.[1]

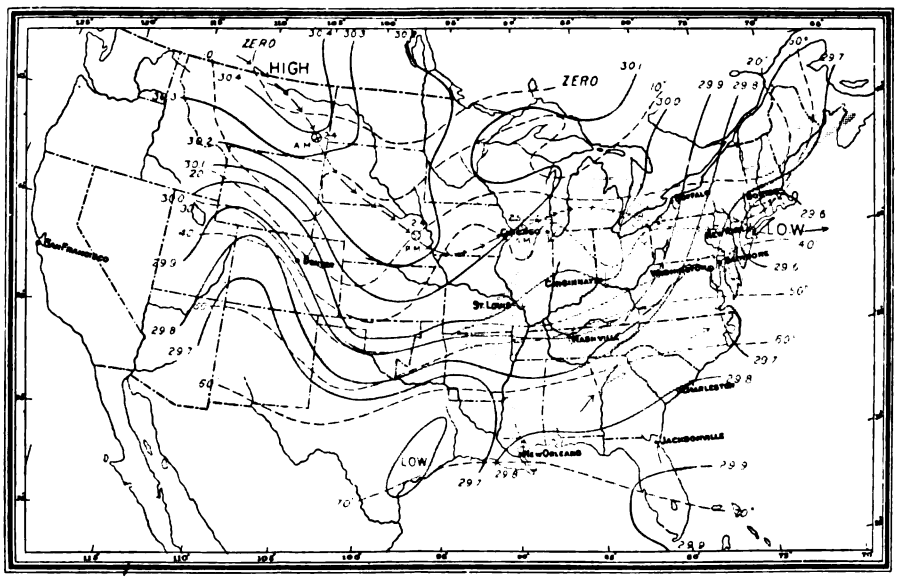

FIG. 42.—Lake type, March 26, 1899.

[1] Solid red lines are isobars; broken red lines, isotherms. Scattered arrows show wind direction, and shading indicates area over which precipitation has occurred during preceding 24 hours. The line of heavier arrows shows storm-path, and the circles the location of the storm's center on the date (and time) given.

north to the Lake region, crosses Lake Erie, and proceeds to the New England coast. This is also a common type and occurs with special frequency during the summer. During the passage of this class of storm areas the pressure is usually high in the vicinity of the Gulf and South Atlantic states. In winter it is frequently closely followed by an area of high pressure from the northwest, which also moves much farther south than the high in the Canadian type. As the storm center approaches the Lake region, the winds are easterly to southerly, temperatures rise, clouds form and increase, and if the trough of low pressure, sufficiently developed, extends southward, rain will occur over Maryland during the passage of the center of the storm area along the border of the Lakes. As the center moves across to the north of this state the winds shift to the southwest and then to the west, rain ceases, the air cools, and, in winter time, as the high approaches, a moderate cold wave usually sets in. The northward or southward trend of the low, after reaching the Lake region, considerably modifies the sequence of weather phenomena over this section for this type. If it moves north-northeast, the winds may shift to the west without rain or even without cloud formation, while if it moves east-northeast or east, it produces conditions quite favorable for rain, and, in summer time, conditions most favorable for thunderstorms. Frequently during the midsummer months this is the only type occurring. This type is illustrated in Figure 42, which is a reproduction of the 8 A. M. weather map of March 26, 1899.

TEXAN TYPE.

Another type of conditions is one of low area formation over or near Texas, which passes northeastward across the Central Mississippi valley to Lake Erie, then eastward to the Atlantic coast; during this time an area of high pressure usually covers the Western Plateau region. In case high pressure also exists over the New England states, as frequently happens, considerable resistance is offered to the normal course of the storm, and many modifications in the weather phenomena are produced. When the storm center has reached the Central Mississippi valley cloudiness begins and increases

and brisk northeast winds prevail. Rain sets in as the center moves from the Mississippi valley to the Lake region, with winds shifting to east; rain continues until the center of the area crosses New York state, when the winds shift through south to west, usually with increasing force. With the shifting of the winds to the west, the weather clears and grows colder. One of the marked characteristics of this storm is the heavy precipitation which frequently attends it, extending over the Ohio and Mississippi valleys and Eastern states.

This type occurs most frequently in winter, but often in spring, and now and then in summer time. It is illustrated in Figure 43, which is a reproduction of the 8 A. M. weather map of January 26, 1898.

WEST GULF TYPE.

Another storm type has its origin in the Gulf region, moves across the Mississippi valley to Tennessee and the Ohio valley, and then to the North Atlantic, the center passing near the western border of this state. During the passage of this type, high pressure generally overlies the Western Plateau and the eastern Rocky Mountain Slope region in the beginning; the high drifts southward, then northeastward, closely following the low area. This type produces the heaviest precipitation that occurs over the state, and is always attended by considerable rain. It is frequently attended by easterly gales, changing to westerly, with a rapid fall in temperature as the storm passes. It occurs most frequently in winter but is not unusual during the summer months. The heaviest snow storms of the winter season are most often due to this type. As in the Texan type, the path is sometimes changed by an area of high pressure over the northeast coast. This type is shown in Figure 44, which is a reproduction of the 8 A. M. weather map of December 4, 1898.

EAST GULF TYPE.

It now and then happens, especially if the high pressure area over the Western states is of unusually steep gradient, and attended by low temperatures, that the path of a west Gulf storm is forced far to the east in its earlier movements, causing it to cross the Florida

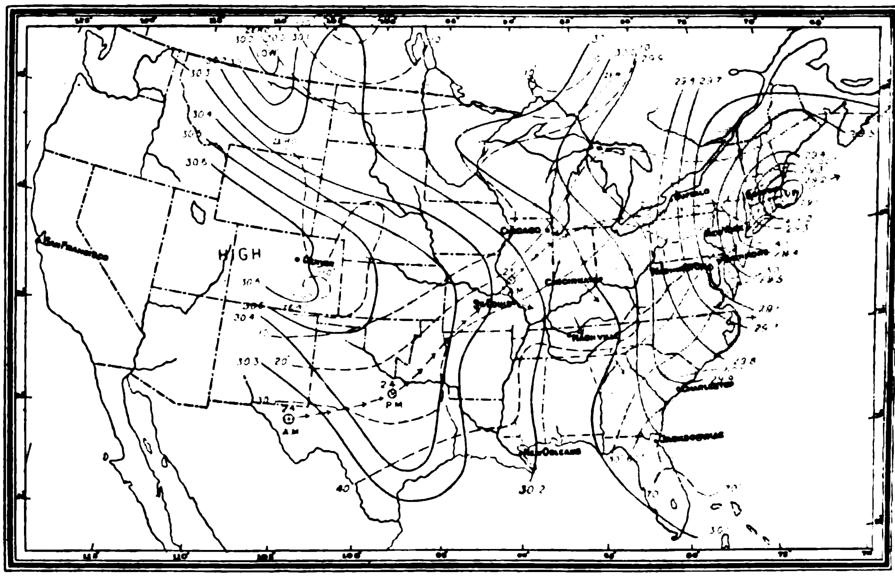

FIG. 43.—Texan type, January 26, 1898.

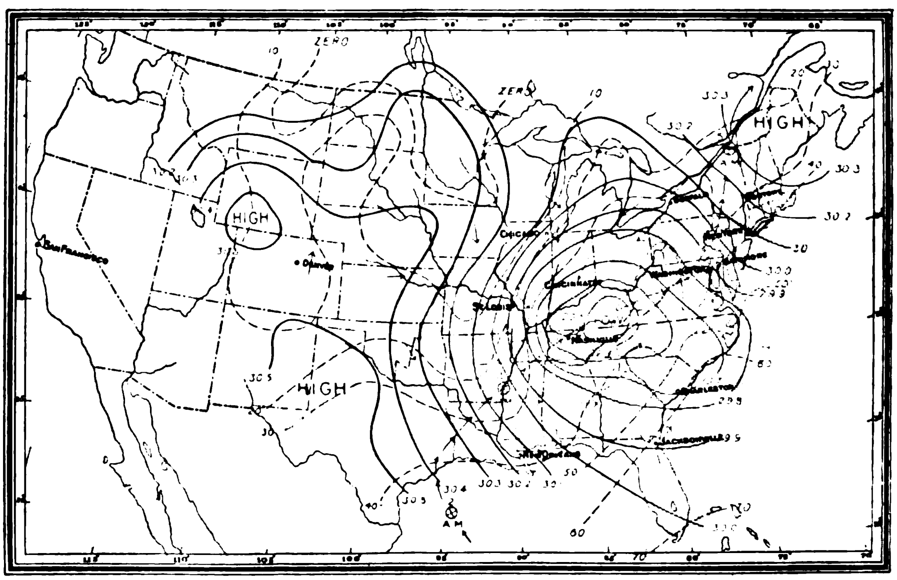

FIG. 44.—West Gulf type, December 4, 1898.

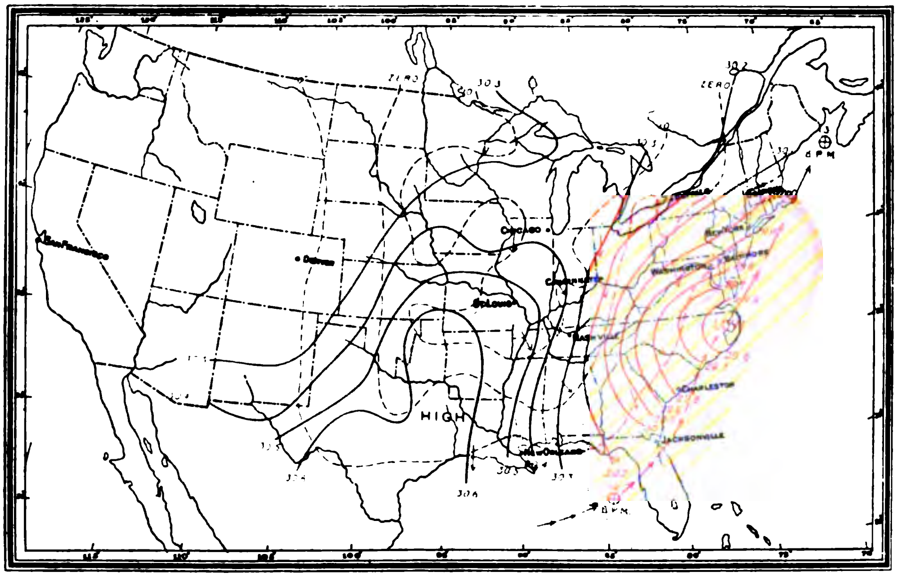

FIG. 45.—East Gulf type, February 13, 1899.

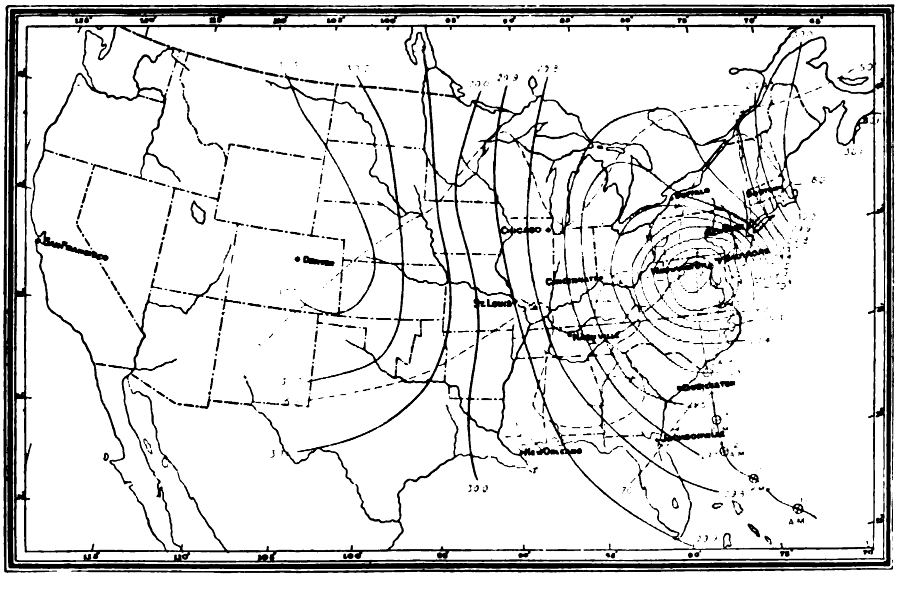

FIG. 46.—West Indian type, October 13, 1893.

peninsula, after which it passes up the North Atlantic coast. This type of storms generally has great violence. In winter it is nearly always attended by heavy rains, changing to snows, and intense northeasterly gales, shifting to westerly after the passage of the storm area to the North Atlantic coast. The heavy snow and blizzard of February 13, 1899, was produced by this type of storm conditions, which is illustrated in Figure 45.

WEST INDIAN TYPE.

Another class of storms has its origin in the West Indies. This type causes the most violent gales of the Atlantic, is very destructive to shipping interests, and occurs during August, September and October, the latter being the month of the greatest frequency. It usually develops in the region of equatorial rains east of the West Indies, moves slowly westward over the West Indies, and in October generally recurves northward over or near the Bahamas. In a few cases during the months stated it passes inland, traverses the Atlantic coast, and occasionally travels northward to the lower Lakes, extending the storm conditions to that region as well. This type of storms is illustrated in Figure 46, which is a reproduction of the 8 A. M. weather map of October 13, 1893.

The storm of November 26-27, 1898, given in Figures Nos. 21-26, pp. 244-246, in Professor Abbe's article, in this volume, illustrates another type of conditions which produce destructive storms over the Atlantic coast, but the more violent effects are generally felt north of Maryland. In this particular instance a storm area passed up the coast and was joined off the Jersey coast by another storm area from the Lakes. The combination formed a storm center of tremendous force and energy, which resulted in the loss of much life and property on the New England coast. In this respect its formation was very similar to that of the great snow storm and blizzard of March 11-13, 1888, and also of the severe snow and wind storm of January 31-February 1, 1898. These cyclonic areas were closely followed by the usual high pressure from the west, attended by low temperatures causing rapid condensation and the heavy snows.

The suddenness and violence of these storms, and consequent loss of life, when they reach the North Atlantic coast, are undoubtedly due to the rapid increase of energy which takes place when the two storms meet.

THUNDERSTORM TYPE.

Thunderstorms and excessive rainfalls frequently occur in the summer months without any decided areas of cyclonic or anticyclonic circulation present, being due largely to strong convectional currents that result from the super-heating of the land areas and the drawing in of warm moist air from the water areas. An arrangement, however, that will usually produce thunderstorms over this section is the presence of an area of low pressure over the Lower Lake region and an area of relatively high pressure over the Southeastern states. This type is illustrated in Figure 47, which is the reproduction of the 8 A. M. weather map of July 27, 1897.

HAIL TYPE.

As in the case of thunderstorms, there are, frequently, no marked developments of cyclonic circulation attending the occurrence of hail. The arrangement that will usually produce hail in this section is an area of high pressure centered over the South Atlantic states, with a second high area over the Lake region and extending northwest, and a low pressure area off the New England coast. The high in the southeast sends warm, moist air northward, while the high from the northwest sends cold air southeastward. These two currents meet over the Ohio valley and the Middle Atlantic states, and produce the conditions favorable for the formation of hail. This type is shown in Figure 48, which is a reproduction of the 8 A. M. weather map of May 16, 1898.

HOT SPELLS IN SUMMER.

The arrangement that usually produces the hot spells of summer over Maryland is the presence of a more or less permanent high pressure area over the Southeastern states, while a low pressure overlies the northern interior of the continent. This is illustrated in

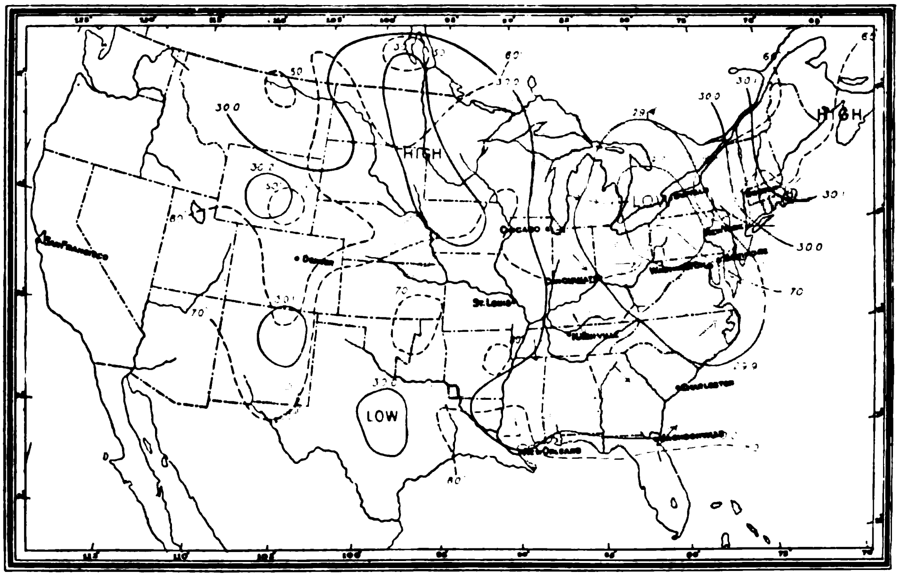

FIG. 47.—Thunderstorm type, July 27, 1897.

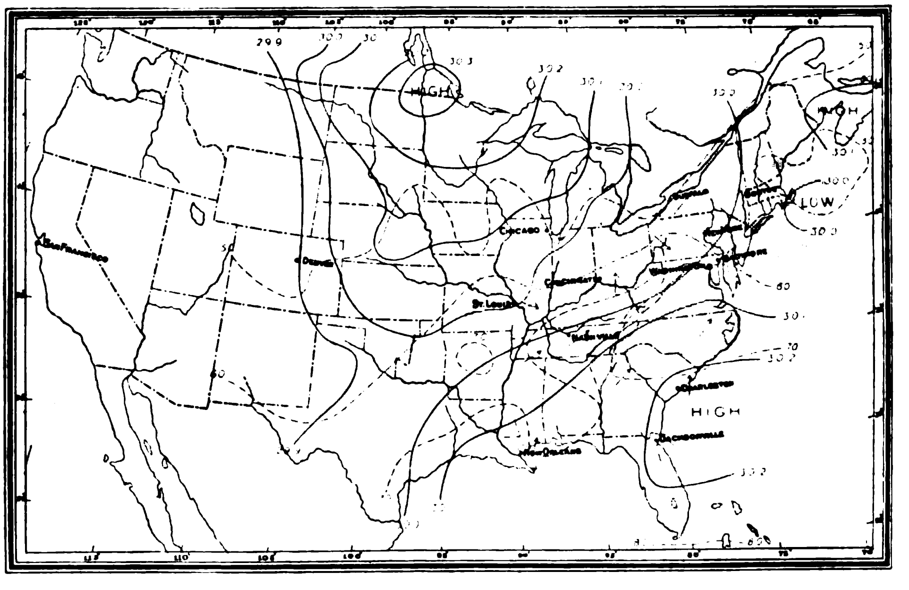

FIG. 48.—Hail type, May 16, 1898.

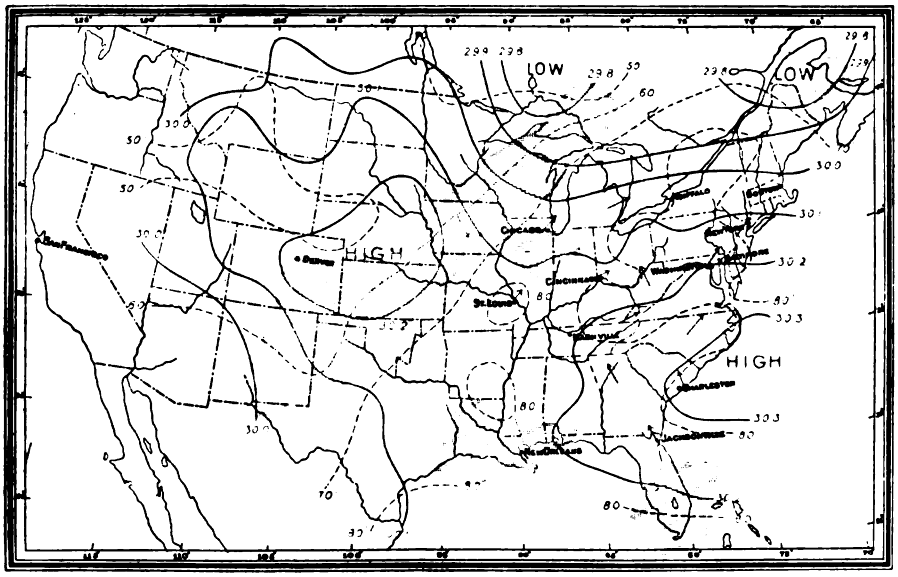

FIG. 49.—Hot spells in summer, July 3, 1898.

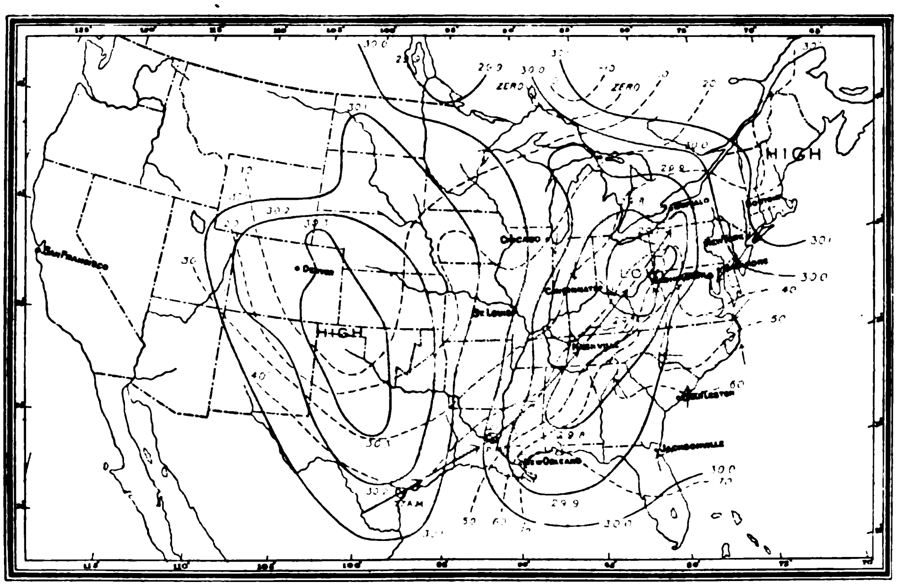

FIG. 50.—Conditions showing local influence of the Alleghany range, March 28, 1899.

Figure 49, which is a reproduction of the weather map of 8 A. M., July 3, 1898. The first appearance of this type in late March or in April is an indication of the breaking up of wintry conditions, and heralds the advent of spring.

LOCAL INFLUENCE OF ALLEGHANY RANGE.

The modifying influence of the Alleghany range of mountains on the temperatures attending the passage of storm areas over the Ohio valley is at times quite marked. An area of low pressure centered in the Ohio valley ordinarily gives a considerable rise in temperatures over Maryland. But it occasionally happens that an area of high pressure is at the same time located over the New England coast, and in that case the colder winds blowing from the high toward the low pressure are held east of the mountains by their elevation; consequently cold northeast winds are forced southward over Maryland and as far south as the Carolinas, intercepting the warm southeast air currents that would prevail if the mountains did not interfere with the more direct flow of the air toward the storm center. This illustrates the cooling influence of the mountains, and an example is given in Figure 50, which is a reproduction of the 8 A. M. weather map of March 28, 1899.

At times the mountains exert a warming influence, or at least afford protection against a degree of cold that would otherwise occur over the state. When a high pressure area attended by a cold wave approaches from the west, it is frequently deflected far southward to the Gulf region, and the cold winds instead of blowing directly from the west flow around the southern portions of the Alleghany range and approach the Middle Atlantic states from the southwest. In such cases the cold wave is frequently more severe in Georgia and South Carolina than in Maryland.

CLIMATE.

The Physical Features of Maryland.

A necessary prelude to the discussion of the climate of Maryland is an intimate knowledge of its geographical location and physiographic

FIG. 51.—Photograph of model of Maryland.

features. The most trustworthy information respecting these conditions is found in the Reports of the Maryland Geological Survey,[1] and it has been thought advisable to present a general description of these features based on the writings of Professor William Bullock Clark, State Geologist.

Maryland is situated between the parallels of 37° 53′ and 39° 44′ north latitude, and the meridians of 75° 04′ and 79° 33′ + west longitude, the exact western boundary being yet undetermined. Its boundaries are: Mason and Dixon's line, separating it from Pennsylvania on the north; the state of Delaware and the Atlantic ocean on the east; on the south Virginia and West Virginia, separated by a line drawn from the ocean to the western bank of the Potomac river, and thence following the western bank of that river to its source; and on the west, West Virginia, separated by a line drawn due north from this source to Mason and Dixon's line. The gross area of the state is 12,210 square miles, of which 9860 square miles are land surface; the included portions of Chesapeake bay, 1203 square miles; Chincoteague bay on the Atlantic coast, 93 square miles, and 1054 square miles of smaller estuaries and rivers.

When we come to examine the physical features of the state of Maryland we find the greatest diversity in surface configuration and mineral contents. From its eastern to its western borders may be found a succession of districts suitable from their physical surroundings for the most diverse employments. Maryland possesses portions of all the characteristic divisions of the eastern United States, and there is no state in the country which has a greater variety in its natural surroundings. In its physiographic features it is closely related to the states which lie to the north and south of it. It is part of the eastern border region which stretches from the Atlantic coast-line to the crest of the Alleghanies and from its central situation affords, perhaps, the most characteristic section of this broad belt. The country rises from the sea-level at first gradually and then more rapidly until it culminates in the highlands of the western

[1] Maryland Geological Survey, Vol. I, 1897; Maryland Geological Survey, Vol. III, 1899.

portion of the state. It has been divided throughout the middle Atlantic slope into three physiographic areas known respectively as the Coastal Plain, the Piedmont Plateau and the Appalachian Region. All are typically represented within the area of the state of Maryland and have conditioned to a marked extent its economic development.

THE COASTAL PLAIN.[1]

The Coastal Plain includes the eastern margin of the Atlantic slope extending from the edge of the continental shelf on the east to the head of tide on the west, the latter reaching to a line extending across the state from northeast to southwest from Port Deposit, past Baltimore, to Washington. This region is divided into a submarine province and a subaërial province, the former extending from the edge of the continental shelf to the present continental border; the latter from the land margin to the head of tide as above described. For our present purpose it will be unnecessary to consider further the submarine province.

The subaërial province, which includes the eastern and northern counties of the state, comprises nearly 5000 square miles, or somewhat over one-half the land area of the state. It is formed, for the most part, of level areas of lowland which extend with gradually increasing elevation from the coastal border, where the whole surface stands very nearly at sea-level, to heights of three hundred feet and more along its western edge. The region is cut quite to the border of the Piedmont Plateau by tidal estuaries, and the topography becomes more and more pronounced in passing inland from the coast. The Chesapeake bay extends nearly across its full length from south to north, while the larger rivers and their tributaries deeply indent the country in all directions, making the coast-line of Maryland the longest of any state in the country. The drainage of the region, except near the margin of the Coastal Plain, and in some of the larger rivers which rise without the area, is consequent upon the present surface of the land, but has been consideraly modified by oscillations

[1] A much fuller discussion of these physiographic areas has been given by Professor Cleveland Abbe, Jr., in Part II of the present volume.

in level. These oscillations have left the lower courses of the streams submerged, producing the Chesapeake bay and the other tidal estuaries of the state.

The subaërial portion of the Coastal Plain in Maryland may be divided into a lower eastern and a higher western division, separated by the Chesapeake bay. The former is known under the name of Eastern Maryland or the Eastern Shore, while the latter is commonly referred to as Southern Maryland or the Western Shore.

The *eastern division* includes the counties of Worcester, Somerset, Dorchester, Caroline, Talbot, Queen Anne's, Kent and part of Cecil. To this region most of the state of Delaware also properly belongs. Nowhere, except in the extreme north, does the country reach 100 feet in elevation, while most of it is below 25 feet in height. Both on the Atlantic coast and more especially upon the shores of the Chesapeake bay it is deeply indented by bays and estuaries. The Atlantic coast especially shows very strikingly the result of sand-bar construction and the lagoons and inlets which are formed in consequence of it. The drainage of the region is simple, the streams flowing from the watershed directly to the Atlantic ocean and Delaware bay upon the east, and to the Chesapeake bay upon the west. The position of the watershed along the extreme eastern margin of the area is very striking; in Worcester county for much of the distance it is only a few miles distant from the Atlantic shore, and as a result the streams which flow to the east are small in comparison to those which drain toward the west. Among the most important rivers which reach the Chesapeake bay from this area are the Pocomoke, Nanticoke, Choptank and Chester, which all have their headwaters within the state of Delaware, and flow in a general southwest direction in sinuous channels.

The *western division* includes the counties of St. Mary's, Calvert, Charles, Prince George's, Anne Arundel, and portions of Baltimore, Harford and Cecil. In elevation this region stands in striking contrast to the eastern division, since it frequently has an altitude of 100 feet even along its eastern margin. In lower St. Mary's county the land reaches an elevation of 100 feet on the Bay shore, which is

gradually increased westward, until, near the border of Charles county, it slightly exceeds 180 feet. In southern Calvert county an elevation of 140 feet is found to the west of Cove Point and this gradually increases to the northward and northwestward until near the southern border of Anne Arundel county the land rises above 180 feet. Throughout the western portion of this division in Charles, Prince George's and Anne Arundel counties the land gradually increases in height to the contact of the Piedmont Plateau, reaching 280 feet to the east of Washington and very nearly the same elevation in the area to the south of Baltimore. Outlying patches of the Coastal Plain, as determined by their geological characteristics, are found to the westward at still higher elevations. This western division is traversed by several rivers which flow from the Piedmont Plateau, among the more important being the Potomac, Patuxent, Patapsco, Gunpowder and Susquehanna. The course of the Potomac is especially striking. After flowing in a nearly southeast direction across the hard rocks of the Piedmont Plateau, it is apparently abruptly turned aside by the soft materials of the Coastal Plain, and takes a course for forty miles nearly at right angles to that which it formerly held. It turns again by a long sweep to the southeast and continues in that direction to the Chesapeake bay. The local drainage of the western division possesses the characteristics which have already been described for the eastern section, in that the streams throughout Southern Maryland flow chiefly to the westward. For example, the watershed of the country lying between the Chesapeake bay and the Patuxent river is situated but a slight distance from the shores of the former, so that most of the natural drainage of Calvert county reaches the Patuxent river. A still more striking exhibition of this is seen in St. Mary's, Charles and Prince George's counties, where the streams nearly all flow to the Potomac river, the watershed of the region approaching very close to the valley of the Patuxent. The same peculiarity in the drainage is found to the southward in Virginia and the Carolinas.

THE PIEDMONT PLATEAU.

The Piedmont Plateau borders the Coastal Plain upon the west and extends to the base of the Catoctin Mountain. It includes ap-

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proximately 2500 square miles, or somewhat over one-quarter of the land area of the state. It is about 65 miles in width in the northern portion of the region, but gradually narrows toward the south until it becomes somewhat less than 40 miles broad. It includes all, or the greater part, of Montgomery, Howard, Baltimore, Harford, Carroll and Frederick counties. The region is broken by low, undulating hills which gradually increase in elevation from its eastern margin until they culminate near the central portion of the area in Parr's Ridge. This ridge divides the district into an eastern and a western division, the latter gradually sloping into the Frederick Valley. The major drainage of the area shows but little relation to the underlying rocks, but gives evidence of having been superimposed through a cover of sedimentary materials which may have been the westward extension of the present Coastal Plain, although more recent adjustments to the underlying rocks have taken place.

The *eastern division* of the Piedmont Plateau has, on account of its varied crystalline rocks and their complicated structure, a highly diversified topography. Along the eastern margin the land attains at several points heights exceeding 400 feet; while at Catonsville it reaches 535 feet above the sea-level. Towards the west and northwest the land gradually increases until it culminates in Parr's Ridge, which exceeds 850 feet in Carroll county. The drainage of the eastern division is mainly to the east and southeast. On its northern and southern borders it is traversed by the Susquehanna and Potomac rivers, which have their sources without the area, while the smaller streams which lie between them drain directly to the Chesapeake bay or into the main rivers. Among the most important of these intermediate streams are the Gunpowder, Patapsco and Patuxent rivers, whose headwaters are situated upon Parr's Ridge. The Patapsco flows in a deep rocky gorge until it reaches the Relay, where it debouches into the Coastal Plain. All of these streams have rapid currents as far as the eastern border of the Piedmont Plateau, and even in the case of the largest are not navigable. The broad, fertile limestone valleys to which the present drainage has become partially adjusted are a striking feature of this area and are well represented

to the north of Baltimore in the Green Spring and Dulaney's valleys. On account of the complicated character of the stratigraphy, which will not be discussed, the valleys take different directions and are of very variable form and extent.

The *western division* extends from Parr's Ridge to the Catoctin Mountain. Along its western side is the broad limestone valley in which Frederick is situated and through which flows the Monocacy river from north to south, entering the Potomac river at the border line between Montgomery and Frederick counties. The valley near Frederick has an elevation of 250 feet above tide, which increases slowly to the eastward towards Parr's Ridge and very rapidly to the westward toward the Catoctin Mountain. Situated on the eastern side of the valley, just at the mouth of the Monocacy river and breaking the regularity of the surface outline, is Sugar Loaf Mountain, which rises rapidly from the surrounding plain to a height of 1250 feet. With the exception of a few streams which flow into the Potomac directly, the entire drainage of the western district is accomplished by the Monocacy river and its numerous tributaries, the latter flowing in nearly parallel west and east courses from Parr's Ridge and the Catoctin Mountain. The deeper portions of the valley are considerably to the west of the centre of the district, and as a result the streams upon the east are longer and of greater volume than those upon the west. The water-ways at a distance from the main valley flow in marked channels, which are frequently deeply cut in the land.

THE APPALACHIAN REGION.

The Appalachian Region borders the Piedmont Plateau upon the west and extends to the western limits of the state. It comprises about 2000 square miles, or somewhat less than one-sixth of the area of the state and has a width of about 115 miles east to west. It includes the western portion of Frederick and all of Washington, Allegany and Garrett counties. This area consists of a region of parallel mountain ranges with deep valleys which are cut, nearly at right angles, throughout much of the distance, by the Potomac river. Many of the ranges exceed 2000 feet, while some reach 3000 feet and more

in the western portion of the mountainous area. The country illustrates in an exceptional manner the type of adjusted drainage. The Appalachian Region is divided into three distinct physiographic districts, based upon clearly defined geological differences, viz., an eastern (Blue Ridge), a central (Great Valley and Appalachian Mountains proper), and a western (Allegany Mountains) division.

The *eastern division* comprises the area between the Catoctin and Blue Ridge mountains with a width of about fifteen miles from east to west along the Potomac, but gradually narrowing northward until it is not more than nine miles in width at the Pennsylvania line. Along the eastern border of this region the Catoctin Mountain extends from north to south, beginning in the highlands of Pennsylvania and reaching to the Potomac river at Point of Rocks. This range has an altitude of about 1800 feet in Maryland. Succeeding the Catoctin Mountain upon the west is the Middletown Valley, with an elevation of 500 feet at Middletown. The valley drains southward into the Potomac river through the Catoctin creek and its tributaries which receive their waters from the western flank of the Catoctin Mountain and the eastern slope of the Blue Ridge. The Blue Ridge of Maryland is a continuation of the South Mountain of Pennsylvania and extends as a sharply defined range from the northern border of the state to the Potomac river, which it reaches at Weverton. Its crest forms the border between Frederick and Washington counties. The Blue Ridge reaches its greatest elevation of about 2400 feet at Quirauk, not far from the Pennsylvania border. The Blue Ridge in Virginia is not the direct continuation of the mountains so named in Maryland, but of a smaller range, the Elk Ridge Mountains, which adjoin them upon the west and which are pierced by the Potomac river at Harper's Ferry.

The *central division*, known as the Greater Appalachian Valley, which includes the Appalachian Mountains proper, is bounded upon the east by the Blue Ridge and upon the west by the Alleghany Plateau. It is divided into two subdivisions, the Great Valley upon the east and the Alleghany Ridges upon the west.

The Great Valley has a width of about twenty-five miles with an

elevation slightly exceeding five hundred feet at Hagerstown which increases somewhat to the northward near the Pennsylvania line but declines in the vicinity of the Potomac river. The Great Valley is often referred to in Maryland as the Hagerstown Valley from the well-known city of that name which is situated in the centre of the district. The Antietam river and its tributaries occupy the eastern section of the valley and the Conococheague river and its tributaries the western, leaving the central portion of the valley somewhat higher than the sides.

The western subdivision comprising the Alleghany Ridges has a width of about fifty miles and consists of a succession of parallel sandstone ridges with intervening limestone and shale valleys.

> "It is a complex chain of lông, narrow, very level mountain ridges, separated by long, narrow, parallel valleys. These ridges sometimes end abruptly in swelling knobs, and sometimes taper off in long, slender points. Their slopes are singularly uniform, being in many cases unvaried by ravine or gully for many miles; in other instances they are trenched at equal intervals with great regularity. Their crests are, for the most part, sharp, and they preserve an extraordinarily equable elevation, being only here and there interrupted by notches or gaps, which sometimes descend to the water level, so as to give passage to the rivers [Potomac] . . . The riages are variously arranged in groups with long, narrow crests, some of which preserve a remarkable straightness for great distances, while others bend with a prolonged and regular sweep. In many instances two narrow contiguous parallel mountain crests unite at their extremities and enclose a narrow oval valley, which, with its sharp mountain sides, bears not infrequently a marked resemblance to a long, slender, sharp-pointed canoe."[1]

Among the more important ridges in Maryland west of North Mountain are Tonoloway Hill, Sideling Hill, Town Hill, Green Ridge, Warrior Ridge and Martin's Ridge, the latter reaching 2000 feet and upwards in elevation. They are arranged in groups of three parallel and closely adjoining ridges on the eastern and western sides with more distant ridges in the middle of the district. The drainage of this area is altogether to the southward into the Potomac river. The deeper valleys in the eastern portion of the region have an elevation of about 500 feet in their lower portions near the Potomac river,

[1] Rogers, H. D., Geology of Pennsylvania.

but they gradually become higher toward the west. Evitt's creek at its mouth near Cumberland has an elevation of about 600 feet above sea-level.

The *western division*, known as the Alleghany Plateau, forms the extreme western portion of the state, including western Allegany and Garrett counties. It is bounded upon the east by Dan's Mountain, the eastern slopes of which are referred to under the name of the Alleghany Front. To the west of Dan's Mountain the country descends into the broad synclinal represented in the George's Creek Valley, rising beyond into Savage Mountain, which is extended southward along the left bank of the North Branch of the Potomac river under the name of the Back Bone Mountain. This high ridge, which throughout much of its extent constitutes the divide between the easterly and westerly flowing streams, is the highest portion of the state and reaches elevations at several points of more than 3000 feet. The Savage river alone penetrates this highland and to-day drains the district lying between Savage and Meadow mountains. The region to the west of the main divide forms a high plateau with gently undulating mountains rising from its surface. The main ranges to the west of Meadow Mountain are Winding Ridge and Laurel Hill which, however, at no point reach the high elevation attained by Savage and Back Bone mountains. All of Garrett county to the west of Back Bone and meadow mountains has its drainage to the westward into the Ohio basin through the Castleman and Youghiogheny rivers, the two latter streams uniting beyond the limits of the state and sending their waters to the Ohio by way of the Monongahela river. This division of the drainage of the Alleghany Plateau has particular interest, since the waters flow, on the one hand, directly to the Atlantic ocean by way of the Potomac river, while in the other case they follow the circuitous route to the Gulf of Mexico by way of the Ohio and Mississippi rivers.

The Climatic Elements.

In attempting to determine the value of an element or condition and to form a definite idea of its variations or of its relations to other

elements or conditions, it becomes necessary to fix upon a convenient unit of measure. A system of such units has been adopted for the measurement of the elements that constitute climate,—as for example, degrees for heat, inches for precipitated moisture, miles per hour for wind movement, and terms of percentage for cloudiness and the amount of aqueous vapor in the air. The expansion or contraction of the mercurial column in the thermometer, as shown by the graduated scale, indicates the fluctuations of temperature, and the number of inches found in the rain gauge is a measure of the precipitation. Familiarity with these units of measure through their prolonged use enables one to appreciate their full meaning, and quickly to associate a temperature of 45 degrees or a rainfall of two inches with a certain feeling of personal comfort or with a probable effect upon organic life in general.

In endeavoring to describe the elements that constitute the climate of a country it is necessary to use these units, and also to establish an additional standard of reference in order that throughout the discussion the many irregular variations of temperature, moisture, etc., may be made comparable to some fixed quantity. The standard of reference usually chosen is what is called the *normal condition.*

This is determined by reducing the known facts regarding an element—including all its variations and extremes—to a single average. In some fields of investigation this normal has in itself an actual value, inasmuch as it indicates an habitual state, but in meteorological and climatic studies the condition thus expressed is more often an ideal than an actual one. Thus, when it is said that the normal annual temperature for Maryland is 54 degrees, one has expressed a fact that has but a limited value in an absolute sense, but which, nevertheless, is of great importance in affording a standard of reference from which to measure the temperature departures that are found in the various parts of the state, as well as the marked variations that occur at any one place in the different months. It is not to be understood that these normals are without individual worth; properly supported by statements of average and extreme departures, they assume a concrete meaning; but it should be borne in mind that when a normal condition is mentioned, it is to afford a basis for a

further development of the subject rather than to express an estimate of an habitual state.

Temperature.

NORMAL ANNUAL TEMPERATURES.

The normal annual temperature for Maryland is between 53° and 54°. The principal modifying influences that determine the departures from this normal in the various climatic divisions of the state are latitude, water areas and elevation. The highest normal annual temperatures are found over the extreme southern counties of the Eastern and Western shores. The influence of the Bay causes an appreciable, but not very decided, increase in annual temperatures along either side as compared with the level land areas closely adjoining. Over these latter areas the temperatures are very much the same, and differ but slightly from the normal for the entire state. The lowest normal annual temperatures occur in the western part of Garrett county, where they range from 46° at stations on the higher mountain ridges to 48° in the plateau region lying to the north. Eastward from these higher elevations the increase in temperature is very rapid with the descent towards sea-level; a normal annual of 52° is reached in the western part of Allegany county, and an approach very nearly to the state normal is found in some of the valley depressions. No satisfactory records are obtainable for the annual temperatures of the Blue Ridge, although it is likely that the decrease of temperature for increase in elevation is about uniform with that found in the Alleghanies. Annual temperatures of 52° or below prevailed over the northern portions of the Piedmont Plateau, and thence increase gradually towards the normal conditions found southward over the interior.

Within these several larger divisions there are limited areas over which are found an excess or deficiency in normal annual temperatures, as compared with the neighboring localities. These exceptions probably arise from local causes not yet determined. It is probable, too, that the high annual temperatures of the more southern counties are due in part to the character of the soil as well as to latitude; since, theoretically, the temperature there should average about 57°, instead

NORMAL MONTHLY, SEASONAL AND ANNUAL TEMPERATURES.

RECORD FOR FIVE YEARS OR OVER.

STATIONS.	No. Years Record.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Annual.	Spring.	Summer.	Autumn.	Winter.
Annapolis	22-26	34	36	42	53	64	74	79	77	70	57	46	38	56	53	77	58	36
Bachman's Valley..	5-6	29	29	40	50	62	70	75	72	65	51	41	32	51	50	72	53	30
Baltimore	45-48	33	35	42	53	63	73	77	75	68	56	45	37	55	53	75	56	35
Bladensburg	9-11	32	34	41	52	63	72	76	75	64	55	44	34	53	52	74	54	33
Boettcherville	7-8	28	31	40	50	62	71	74	71	65	52	41	35	52	51	72	53	32
Charlotte Hall	5-6	35	35	45	54	....	73	76	76	....	56	47	38	....	....	75	....	36
Cherryfields	5-6	35	34	44	53	64	73	76	75	71	58	47	38	56	54	75	59	36
Chestertown	8-13	32	33	42	51	63	71	76	74	70	55	46	36	54	52	74	56	34
College Park	6-8	34	35	44	53	63	72	74	74	69	55	46	39	55	54	73	57	36
Cumberland........	8-10	35	37	42	55	66	74	76	75	69	56	46	38	56	54	75	57	37
Cumberland........	24-25	31	33	38	51	62	70	73	71	65	53	41	34	52	51	72	53	33
Darlington	7-8	30	30	41	51	62	71	75	73	67	53	43	35	53	51	73	55	32
Deer Park..........	5-6	26	28	35	....	....	....	....	...	....	47	38	28	....	....	....	...	27
Del. Breakwater...	5-6	33	37	40	48	60	68	73	72	70	61	48	38	54	51	71	59	36
Denton	5-6	....	34	42	53	63	73	76	....	....	....	....	....	....	53	....	....	....
Distrib. Reservoir .	7-8	32	34	43	54	65	75	77	76	69	56	45	37	55	54	76	57	34
Dover, Del	16-19	34	35	42	53	64	73	77	75	68	56	45	36	55	53	75	56	35
Easton..............	7-8	33	35	44	54	64	72	76	75	69	57	46	37	55	54	75	57	35
Ellicott City........	5-6	33	....	....	54	64	....	....	....	....	....	46	36	....	....	....	....	35
Fallston	26-29	30	32	38	50	61	70	74	72	66	54	43	34	52	50	72	54	32
Fort Delaware	19-21	32	34	40	52	63	73	78	76	70	57	46	38	55	54	75	58	35
Fort Foote	7-8	33	34	41	52	64	74	78	75	66	55	42	34	54	52	75	54	34
Fort McHenry	56-60	33	35	42	53	63	72	77	75	68	57	45	36	55	53	75	57	34
Fort Washington ..	17-20	36	38	46	57	67	76	80	77	69	59	47	37	58	57	78	58	37
Fort Severn	7-8	33	35	43	54	65	73	78	76	69	58	47	37	56	54	76	58	35
Frederick	22-24	32	34	41	52	63	72	76	74	67	55	44	35	54	52	74	55	34
Grantsville	5	....	....	....	....	....	....	....	67	63	49	39	31	....	....	....	51	....
Great Falls..........	7-8	31	34	42	53	65	74	76	75	68	55	44	36	54	54	75	56	34
Green Sp. Furnace.	5-6	29	32	39	51	62	73	76	75	68	52	42	33	53	52	75	54	31
Jewell	7-10	34	36	42	55	64	73	76	76	70	55	46	38	55	54	75	57	36
Kirkwood, Del.....	6-7	31	31	37	51	62	74	75	76	68	54	42	35	53	50	75	55	32
Mardela Springs ...	10-11	36	37	43	53	63	72	75	75	68	55	47	39	55	53	74	57	37
McDonogh	20-23	31	34	39	51	62	71	74	72	66	55	44	35	53	51	72	55	33
Milford, Del.........	14-16	36	35	43	52	62	72	77	75	67	55	45	38	55	52	75	56	36
Millsboro, Del......	6	33	34	44	53	63	72	76	75	69	56	47	39	55	53	74	57	35
Mt. St. Mary's......	23-33	30	33	39	51	61	70	75	72	65	54	42	33	52	50	73	54	32
Newark, Del	5	....	....	....	50	62	70	75	74	68	54	44	36	...	....	73	55	....
New Market........	10-13	30	33	40	51	63	73	77	74	66	55	43	35	58	51	75	55	32
Pocomoke City.....	5	....	....	49	56	66	74	78	77	....	60	53	43	....	57	76	....	....
Princess Anne	23-25	38	39	47	56	64	72	77	76	70	57	49	41	58	56	75	58	39
Receiv'g Reservoir	7-8	32	34	43	54	65	74	77	76	68	56	45	36	55	54	76	56	34
St. Inigoes	7-9	38	43	44	55	65	74	79	76	69	59	50	40	58	55	76	59	40
St. Mary's	6-9	35	37	43	55	62	73	76	....	71	58	47	39	....	53	....	59	37
Sandy Spring.......	7-8	36	35	40	51	63	71	76	72	66	58	43	36	58	51	73	56	33
Schellman Hall	20	32	34	41	51	63	70	74	72	66	54	44	34	53	51	72	55	33
Seaford, Del........	5-7	34	35	43	54	63	71	75	75	69	56	46	38	54	53	74	57	35
Solomon's	7	34	36	44	53	65	74	78	78	72	59	49	39	57	54	77	60	36
Sunnyside	6	24	25	36	46	56	64	67	65	61	48	37	30	47	46	66	49	26
Washington	25	33	36	41	53	64	73	77	75	68	56	44	36	55	53	75	56	35
Woodlawn..........	11	30	31	38	50	61	72	75	73	66	53	42	33	52	50	73	54	31
Woodstock	22-28	32	33	39	51	62	71	75	72	65	53	42	34	52	51	72	53	33

of nearly two degrees higher. No attempt will be made, however, other than in a general way, to account for the lesser or strictly local temperature modifications unless the cause is very clearly indicated.

NORMAL MONTHLY TEMPERATURES.

The normal temperatures for months, seasons and year, are given in the accompanying table. Considering the state as a whole, a

lowest normal temperature of 31° is found in January, and a highest of 75.5° in July. Between these two extremes the normals for other months can be arranged, and a curve drawn, Figure 52, that will graphically represent the advancing or retrograde movement that takes place in the normal temperatures during the year. It will be seen in so doing that the change is least marked from December to

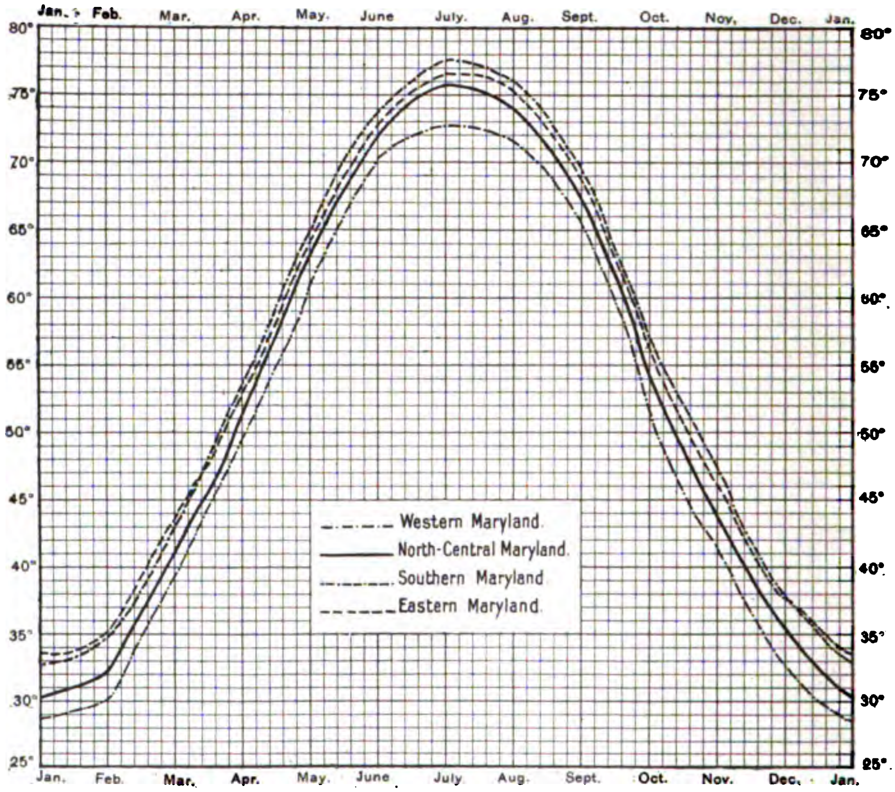

FIG. 52.—Mean temperatures in the four climatic divisions of Maryland.

January, January to February, and July to August. The normal temperature for August is about 1.5° less than for July, while the February normal is about 2° greater than for January. The change from June to July is also moderate, although greater than that which occurs between the months already mentioned. For the remaining

months the progress toward one extreme or the other is quite marked, and amounts to over ten degrees in late spring, early summer and late autumn. The seasonal normals show a greater variability. Spring is about eighteen degrees warmer than winter, and summer about twenty-two degrees warmer than spring; the same rate of decrease holds good for autumn and winter when a comparison is made of their normals with the normal for the season immediately preceding. The next table gives the rate of normal temperature change from month to month and season to season at the various stations in Maryland and Delaware. The table discloses several local peculiarities: For a few of the stations the records for five years or more give for February a normal monthly temperature below that for January, while August is as warm as July, and, at one place, even warmer. In the cases cited, the normals have been determined from a seven to ten year period of observations, and it is more than likely that, in time, they will be so changed as to agree with the arrangement of the monthly normals as found elsewhere throughout the state.

MONTHLY TEMPERATURE DISTRIBUTION.

It will be seen from Figure 52 that no very decided contrasts are shown in the normal monthly temperatures for the several climatic divisions of Maryland, as the general trend of the curves conform, and the lines are not widely separated. This is principally due to the fact that areas of great differences in elevation have been embraced in the same general division, thereby obscuring to a certain extent in the averages the marked thermal features found in the mountains, especially in western Maryland. It will therefore be necessary to consider more limited localities to obtain an idea of the range of these conditions within the state limits. The facts are brought out in Figure 53, in which the state monthly normals are placed on a common plane of reference and indicated by the straight line, while the irregular lines define the greatest concurrent monthly ranges above and below the normal, as obtained from the records of the stations showing these extremes. The greatest ranges above the state normal have been obtained, invariably, from the records made in the southern counties of the Eastern and Western shores, while the

greatest ranges below have always been found in the southwestern part of Garrett county, although western Allegany county and the extreme northern portion of the Piedmont Plateau also show radical

THE CHANGE IN MONTHLY AND SEASONAL MEAN TEMPERATURES.

RECORDS FOR FIVE YEARS OR OVER.

STATIONS.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Spring.	Summer.	Autumn.	Winter.
Annapolis	−4	+2	+6	+11	+11	+10	+4	−1	−7	−13	−11	−8	+17	+23	−18	−22
Bachman's Valley	−3	0	+11	+10	+12	+8	+4	−2	−7	−14	−10	−9	+20	+22	−19	−23
Baltimore	−3	+2	+7	+11	+10	+10	+4	−2	−7	−12	−11	−9	+17	+23	−19	−21
Bladensburg	−2	+2	+7	+11	+11	+9	+4	−2	−10	−10	−10	−10	+19	+22	−20	−21
Boettcherville	−7	+3	+9	+10	+12	+9	+3	−3	−6	−13	−11	−6	+19	+21	−19	−21
Charlotte Hall	−3	0	+10	+9	....	....	+4	0	....	....	−9	−9	....	....	....	....
Cherryfields	−3	−1	+10	+9	+11	+8	+4	−1	−4	−13	−11	−9	+18	+21	−16	−23
Chestertown	−4	+1	+9	+9	+12	+8	+5	−2	−6	−13	−9	−10	+18	+22	−18	−22
College Park	−5	+1	+9	+9	+10	+9	+2	0	−5	−14	−9	−7	+18	+19	−16	−21
Cumberland (1)	−3	+1	+6	+13	+11	+8	+2	−1	−6	−13	−10	−8	+18	+21	−18	−21
Cumberland (2)	−3	+2	+5	+13	+11	+8	+3	−2	−7	−11	−8	−9	+18	+22	−19	−21
Darlington	−5	0	+10	+11	+11	+9	+4	−2	−6	−14	−10	−8	+19	+22	−19	−22
Deer Park	−2	+2	+7	....	....	....	....	....	....	....	−9	−10	....	....	....	....
Delaware Breakwater	−5	+4	+3	+8	+12	+8	+5	−1	−2	−9	−13	−10	+13	+22	−22	−13
Denton	....	....	+8	+11	+10	+10	+3	....	....	....	....	....	....	....	....	....
Distribut'g Reservoir	−5	+2	+9	+11	+11	+9	+3	−1	−7	−13	−11	−8	+20	+22	−19	−23
Dover, Del	−2	+1	+7	+11	+11	+9	+4	−2	−7	−12	−11	−9	+18	+22	−19	−21
Easton	−4	+2	+9	+10	+10	+8	+4	−1	−6	−12	−11	−9	+19	+20	−17	−22
Ellicott City	−3	....	....	....	+10	....	....	....	....	....	....	−10	....	....	....	....
Fallston	−4	+2	+6	+12	+11	+9	+4	−2	−6	−12	−11	−9	+18	+22	−18	−22
Fort Delaware, Del	−6	+2	+6	+12	+11	+10	+5	−2	−6	−13	−11	−8	+19	+21	−17	−23
Fort Foote	−2	+2	+7	+11	+12	+10	+4	−3	−9	−12	−12	−8	+18	+23	−21	−20
Fort McHenry	−3	+2	+7	+11	+10	+9	+5	−2	−7	−11	−12	−9	+18	+23	−18	−23
Fort Washington	−1	+2	+8	+9	+10	+9	+4	−3	−8	−10	−12	−10	+20	+20	−19	−21
Fort Severn	−4	+2	+8	+11	+10	+9	+5	−2	−7	−11	−11	−10	+19	+22	−18	−23
Frederick	−3	+2	+7	+11	+11	+9	+4	−2	−7	−12	−11	−9	+18	+22	−19	−21
Grantsville	....	....	....	....	....	....	....	....	−4	−14	−10	−8	....	....	....	....
Great Falls	−5	+3	+8	+11	+12	+9	+2	−1	−7	−13	−11	−8	+20	+21	−19	−22
G. S. Furnace	−2	+2	+7	+12	+13	+8	+4	−1	−7	−16	−10	−10	+21	+22	−20	−23
Jewell	−4	+2	+6	+13	+9	+9	+3	0	−6	−15	−9	−8	+18	+21	−18	−21
Kirkwood, Del	−3	0	+6	+13	+12	+12	+1	+1	−8	−14	−12	−8	+18	+25	−21	−22
Mardela Springs	−2	0	+6	+11	+10	+9	+3	0	−7	−13	−8	−9	+16	+21	−17	−20
McDonogh	−4	+3	+5	+12	+11	+9	+3	−2	−6	−12	−10	−9	+18	+21	−17	−22
Milford, Del	−2	−1	+8	+9	+10	+10	+4	−1	−8	−12	−10	−7	+16	+23	−19	−20
Millsboro, Del	−5	+1	+10	+8	+11	+9	+4	−1	−6	−13	−9	−9	+18	+21	−17	−22
Mt. St. Mary's	−3	+3	+5	+13	+10	+9	+5	−3	−7	−11	−12	−9	+18	+22	−18	−22
Newark, Del	....	....	....	....	+12	+8	+5	−1	−6	−14	−10	−8	....	....	−18	−23
New Market	−4	+3	+7	+12	+11	+10	+4	−3	−8	−11	−12	−9	+18	+24	−21	−21
Pocomoke City	....	....	....	+8	+10	+8	+4	−1	....	....	−8	−9	....	....	....	....
Princess Anne	−3	+1	+8	+9	+8	+8	+5	−1	−6	−13	−8	−8	+17	+19	−17	−19
Receiving Reservoir	−4	+2	+9	+11	+11	+9	+3	−1	−8	−12	−11	−9	+20	+22	−20	−22
St. Inigoes	−2	+5	+1	+11	+10	+9	+5	−3	−8	−9	−9	−10	+15	+21	−17	−19
St. Mary's	−4	+2	+6	+12	+7	+11	+3	....	....	−12	−11	−8	+16	....	....	−21
Sandy Spring	−4	+5	+5	+11	+11	+9	+5	−4	−6	−8	−15	−9	+18	+22	−17	−23
Schellman Hall	−2	+2	+7	+10	+12	+7	+4	−2	−6	−12	−10	−10	+18	+21	−17	−22
Seaford, Del	−4	+1	+8	+11	+9	+8	+4	0	−5	−13	−10	−8	+18	+21	−17	−22
Solomon's	−5	+2	+8	+9	+12	+9	+4	0	−6	−13	−10	−10	+18	+23	−17	−24
Sunnyside	−6	+1	+11	+10	+10	+8	+3	−2	−4	−13	−11	−7	+20	+20	−17	−23
Washington	−3	+3	+5	+12	+11	+9	+4	−2	−7	−12	−12	−8	+18	+22	−19	−21
Woodlawn	−3	+1	+7	+12	+11	+11	+3	−3	−6	−13	−11	−9	+19	+23	−19	−23
Woodstock	−2	+1	+6	+12	+11	+9	+4	−3	−7	−12	−11	−8	+18	+21	−19	−20

departures below the state normal. It is also observed that the extreme range above the normal, all months considered, is not as great as the range below. This is partly due to the fact that the section furnishing

the exceptionally low normal temperatures is small in comparison to the section having the higher normals; therefore the limited areas of high elevation with low temperatures exert but slight influence on the state normals which, in consequence, incline more strongly toward the normals found in the larger area. In February, however, the greatest departure above the normal is larger than the greatest departure below. The explanation for this is that the factors producing climate have a varying influence at different times of the year; latitude and the conserving effects of water surroundings doing more to moderate, than the mountain elevations do to intensify, the cold of winter. In summer the conditions are reversed. The water influences temper the latitude heat in the southern counties, while in the

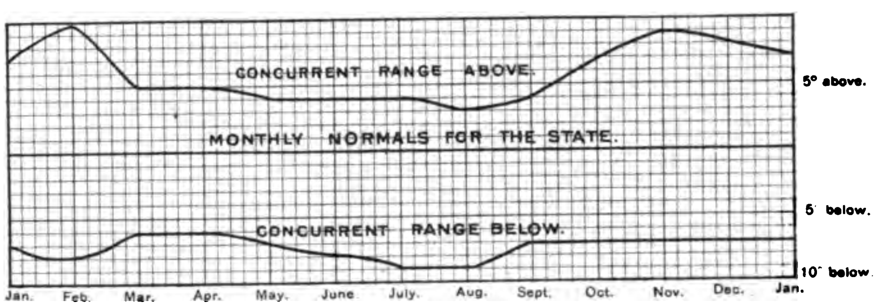

FIG. 53.—The concurrent range of monthly normal temperatures in Maryland.

mountain ranges rapid terrestrial radiation at night is combined with a comparatively low temperature in the day; as a result the greatest summer departures below the state normal occur in the mountains, and amount to nine degrees in July and August, while in the southern and southeastern counties the departures above the normal in those months are only four or five degrees.

Considering Figure 53 once more, and endeavoring to illustrate its general meaning, it may be supposed that a traveler starts from Worcester county, in the month of February, on a journey to the Alleghanies. The normal temperature condition of the place from which he departs is ten degrees above the state normal—in exact figures 41°, or about what prevails in Baltimore toward the close of March.

In crossing the Bay and moving northwestward he finds that the climate grows gradually colder and that the normal temperature conditions for the state are reached in Frederick county. He doubtless experiences considerably lower temperatures in passing over the Blue Ridge, but across Allegany county to the foothills they do not depart greatly from the state normal; here, however, the cold increases rapidly, and when he reaches his destination,—say, Oakland or Sunnyside,—he finds a normal temperature of 23°, or eighteen degrees lower than at Pocomoke City on the same day.

This illustration has been based on the assumption that normal February conditions prevailed throughout the portions of the state mentioned. An example of actual conditions, taken at random from meteorological records, shows that if the journey had been undertaken on Washington's Birthday in 1898, the traveler would have passed from a mean temperature of 45° at Pocomoke City to a mean temperature of 21° at Sunnyside.

Following such a popular method of illustrating the facts given by the diagram, one can easily present to the mind the varying conditions of normal temperature within the state limits for the other months of the year,—as for instance, the range of normal temperature through which the traveler would pass in spring or summer would very likely not exceed eleven degrees.

These illustrations partially indicate the changes that take place along a line from the extreme southeastern to the extreme western portions of Maryland; but in order to arrive at an understanding of the distribution of normal monthly temperatures for all parts of the state, it will be necessary to examine the isotherms that appear on the charts of normal temperature, Plates XXXVIII-LIV. By properly grouping the areas, it is found that certain sections show typical conditions; these for the most part can be explained as due to physical causes, but peculiar conditions appear occasionally that cannot at present be accounted for. The several areas will be considered, first for the types, and second for the local peculiarities.

There is very little difference in the concurrent monthly normal temperatures over the areas lying on either side of the Bay between

Anne Arundel and Kent counties on the north, and lower Calvert and upper Dorchester counties on the south; in the summer months it is about one degree, and at no time in the year is it greater than about three degrees. This general agreement prevails over most of the Eastern Shore and Delaware, between the upper and lower boundaries already defined, except that in January and February the normal temperatures for southeastern Delaware are somewhat lower than in the areas surrounding. An upward trend of the isotherms appears north of Sussex county in Delaware, near the shore-line, although it is not well marked at all times. On the western shore of the Bay the equalizing influence of the waters does not extend inland beyond Anne Arundel, Calvert and lower Prince George's counties.

The monthly normal temperatures increase rather rapidly at times on the Eastern Shore south of a line running east from Dorchester county; this increase amounts to about four degrees from September to December, inclusive, but is not so decided in the other months.

There is a general bend southward in the monthly normal temperatures from the upper Piedmont Plateau to the western part of Baltimore county, and at times the deflection of the isotherms extends to Montgomery county. In Frederick and western Carroll counties the normal temperatures are slightly higher than in the districts adjoining. The Hagerstown Valley and the depressions generally throughout Allegany county are warm compared with the elevated regions on either side. Farther west the differences in elevation cause, in all months, an appreciable difference in the normal temperatures; this is greatest in July and August, when it probably amounts to as much as seven degrees, although the figures are not well shown, being based on interpolations made between the records of the western stations of Allegany county and those of the mountain stations in Garrett county.

The examples of peculiar temperature distribution are found in the southern part of St. Mary's county and in portions of Prince George's and Montgomery counties. In the former section very decided contrasts obtain; the normal temperatures for February differ as much

as five degrees at points not widely separated, and unusual isothermal arrangements are generally noticed in the other months. In the latter area there are several stations which record normal temperatures appreciably lower than found at other stations in the same locality. Whether the differences are due to local causes or to improper exposures of the thermometers is not known. The records have for the present been accepted as representing true conditions, and so used in the preparation of the charts. An extension of the period of observation will determine their value.

LONG PERIOD TEMPERATURE RECORDS.

Thus far the normal rather than the actual temperature conditions have been considered, and consequently a historical statement of just what degrees of average heat have been experienced in the extreme ranges of the normal monthly temperatures has not been given. To do this satisfactorily would require a very long series of observations, representing all parts of Maryland; for it cannot be expected that records for eight or ten years will disclose the true range of average monthly conditions that occur within the state, or even at a single station. There is, however, a series of temperature observations for Baltimore that is almost continuous from 1817 to the present time; and, by adapting observations made during the missing years at other stations to the Baltimore standard, there can be presented an approximately correct history of the monthly and annual mean temperatures at Baltimore for the past eighty-three years. These figures are given in Tables on pp. 482-483. By applying proper reductions to the record for any month or year, it becomes possible to estimate with a fair degree of accuracy the temperatures that have prevailed in any part of Maryland since the beginning of observations at Baltimore.

VALUE OF EARLY TEMPERATURE OBSERVATIONS.

The main features of interest obtainable from this record have been given at the foot of the table, while the absolute range of averages for the period is graphically shown in Figure 54. From the table it will be noticed that nearly all of the extreme temperature departures below the normal are recorded in the early part of the period, while

the extreme departures above have been found more often since 1858 than before that year. This is mentioned not because it leads to the definite conclusion that the average temperature conditions are increasing, but rather to introduce the statement that all early records must be regarded with some suspicion as to their accuracy. The exact conditions under which they were made are not known, but it is evident that they do not as nearly represent true air temperatures as later observations, since only in recent years have the voluntary observers paid especial attention to the proper exposure of their ther-

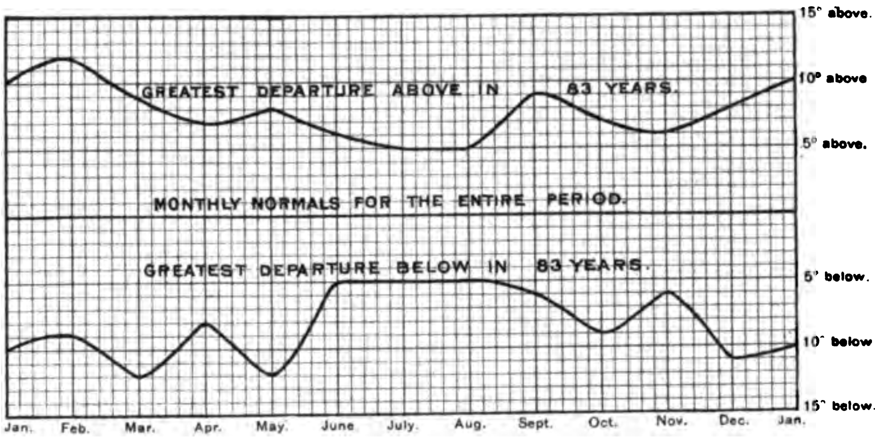

FIG. 54.—Extreme range of monthly mean temperatures at Baltimore in 83 years. (Adapted in part.)

mometers in order to eliminate irregularities due to radiation, influence of soil, etc. Another source of error in the earlier records, in attempting to furnish a true average condition, arose through the use of thermometers that were not self-registering. Those in use at present register accurately the highest and lowest temperatures, and from these extremes the mean temperatures are deduced. With the use of an ordinary exposed thermometer in the earlier observations, there was every likelihood that the eye readings furnished more nearly the minimum than the maximum temperatures, and therefore the temperature deduced would generally be below the true mean.

MEAN TEMPERATURES FOR EIGHTY-THREE YEARS—1817 TO 1899.

ADAPTED TO BALTIMORE STANDARD.

YEAR.	Jan.	Feb.	Mar.	Apr.	May.	Jun.	July.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual.	Authority.
1817	29	27	40	58	59	69	75	72	65	52	47	34	52	Baltimore—Capt. Lewis Brantz.
1818	31	28	40	47	59	71	76	74	63	52	47	30	52	" " "
1819	36	36	37	51	60	73	75	77	69	50	47	34	54	" " "
1820	26	40	42	53	56	69	75	74	67	50	39	32	52	" " "
1821	24	37	38	45	60	74	72	78	69	54	48	34	52	" " "
1822	27	33	44	56	68	72	78	76	70	58	49	36	56	" " "
1823	35	29	42	55	63	69	75	74	66	53	41	37	53	" " "
1824	39	35	41	52	61	70	76	72	65	56	44	40	54	" " "
1825	33	38	45	54	65	74	79	74	66	61	45	33	56	Fort Delaware—Schott's Tables.
1826	36	38	42	47	70	77	77	75	75	57	50	36	57	" " " "
1827	31	41	49	60	62	71	76	75	77	59	45	41	57	" " " "
1828	43	47	51	52	67	79	78	75	67	54	47	40	58	" " " "
1829	34*	30*	40*	54*	66*	72†	75*	75*	62†	55†	42†	38†	54	* Baltimore—Capt. Lewis Brantz. † Fort Delaware—Schott's Tables.
1830	33	30	44	55	63	70	78	77	67	57	45	35	54	Fort Delaware—Schott's Tables.
1831	29	31	47	56	64	76	76	76	67	59	44	25	54	Fort McHenry—U. S. Post Hospital.
1832	32	38	44	53	63	73	76	76	72	59	47	39	56	" " " "
1833	37	37	41	57	70	74	78	74	69	54	44	38	56	" " " "
1834	30	44	47	55	61	73	80	77	67	52	45	36	56	" " " "
1835	32	29	41	49	64	72	76	72	62	57	48	33	53	" " " "
1836	34†	26†	33†	52†	63†	68†	75†	70†	68†	47†	39*	30*	50	* Baltimore—Capt. Lewis Brantz. † Ft. McHenry—U. S. Post Hospital.
1837	27*	33*	39*	47*	60*	68*	75†	74†	64†	55†	47†	36†	52	* Baltimore—Capt. Lewis Brantz. † Ft. McHenry—U. S. Post Hospital.
1838	37	27	43	48	59	75	81	77	68	50	41	31	53	Fort McHenry—U. S. Post Hospital.
1839	32	35	43	56	66	71	77	73	67	59	40	34	55	" " " "
1840	24	39	45	54	61	72	74	74	64	55	43	30	53	" " " "
1841	30	32	40	47	56	71	76	74	71	48	42	35	52	" " " "
1842	36	38	48	54	60	70	75	73	68	53	39	33	54	" " " "
1843	38	28	30	50	51	74	76	76	71	53	42	35	53	" " " "
1844	29	32	42	56	66	70	77	74	67	53	41	33	53	" " " "
1845	37	34	44	55	61	78	76	75	67	55	45	28	54	" " " "
1846	35	32	44	56	66	69	74	75	70	53	48	36	55	Baltimore—Dr. Edmondson.
1847	32	34	40	53	63	72	76	73	66	53	47	36	54	" " "
1848	36	35	39	54	67	74	73	73	64	57	39	42	54	" " "
1849	30	29	41	51	60	74	75	74	66	55	51	33	53	" " "
1850	35	37	39	48	59	74	78	74	66	54	47	36	54	" " "
1851	36	39	44	52	64	72	78	77	68	57	42	29	55	" " "
1852	26	34	42	47	66	72	76	72	65	59	42	40	53	" " "
1853	32*	35*	43*	53*	64*	76*	77*	76*	69*	58*	46*	37†	55	* Baltimore—Dr. Edmondson. † Ft. McHenry—U. S. Post Hospital.
1854	34	36	44	49	64	73	78	75	71	57	51	34	56	Fort McHenry—U. S. Post Hospital
1855	37	29	40	58	65	72	78	76	70	63	49	38	56	" " " "
1856	24	27	34	55	63	77	80	74	68	56	46	34	53	" " " "
1857	23	41	40	46	62	72	75	74	69	55	45	42	54	" " " "
1858	40	30	42	53	60	76	78	74	66	58	42	30	55	Baltimore—Prof. A. Mayer.
1859	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	* Baltimore—Prof. A. Mayer. [illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

[illegible]	[illegible]	[illegible]	[illegible]											
1863	38+	37+	40+	51+	65+	72+	80+	79+	64*	56+	49+	39+	56	* Annapolis—W. R. Goodman. Bladensburg—B. O. Lowndes.
1864	35	39	42	51	68	75	77	78	69	57	48	36	56	Fort McHenry—U. S. Post Hospital.
1865	30	34	49	58	68	77	78	75	74	57	47	38	57	" " " "
1866	31+	36+	44+	56*	63+	74*	79*	71*	70+	57+	50+	34+	55	* Annapolis—W. R. Goodman. + Ft. McHenry—U. S. Post Hospital.
1867	26	29	39	57	61	74	77	75	69	58	49	33	55	Fort McHenry—U. S. Post Hospital
1868	30	28	42	50	62	74	82	78	70	55	47	38	54	" " " "
1869	38	39	41	55	62	74	77	76	70	53	42	39	56	" " " "
1870	40	36	40	55	65	79	82	80	71	59	47	36	58	" " " "
1871	35	40	48	59	65	74	76	77	63	58	45	34	56	Baltimore—U. S. Signal Service.
1872	34	36	37	55	67	75	82	80	69	56	43	32	56	" " "
1873	34	35	39	52	62	74	79	74	67	55	41	40	54	" " "
1874	39	37	44	47	63	76	79	73	70	56	45	38	56	" " "
1875	30	29	40	49	64	74	78	74	66	55	42	38	53	" " "
1876	41	38	40	52	64	76	81	76	65	52	47	28	55	" " "
1877	31	40	41	53	62	74	78	77	68	59	48	43	56	" " "
1878	35	40	49	58	64	70	81	76	69	58	47	35	57	" " "
1879	31	32	44	53	66	73	79	75	65	62	46	42	56	" " "
1880	43	41	43	55	71	75	77	74	68	56	42	31	56	" " "
1881	33	35	42	52	68	71	79	77	77	63	49	44	57	" " "
1882	35	41	45	52	59	74	77	74	69	62	44	37	56	" " "
1883	32	39	39	52	64	75	77	73	65	58	48	39	55	" " "
1884	32	42	44	52	65	73	75	75	72	60	46	37	56	" " "
1885	34	28	35	54	63	73	80	75	67	55	46	38	54	" " "
1886	29	31	42	55	62	70	74	74	70	59	46	31	54	" " "
1887	32	38	38	51	67	72	80	73	65	56	45	37	55	" " "
1888	29	36	37	53	63	73	74	75	64	51	47	36	53	" " "
1889	38	29	43	54	65	71	76	72	66	52	46	44	56	" " "
1890	43	42	40	53	63	75	76	73	67	55	46	34	57	" " "
1891	38*	41*	39*	56*	62*	72*	72+	74+	71+	55+	44+	44+	56	* Baltimore—U. S. Signal Service. + Baltimore—U. S. Weather Bureau.
1892	32	37	37	52	63	76	76	76	66	56	44	33	54	Baltimore—U. S. Weather Bureau.
1893	25	34	40	53	61	72	77	75	67	57	44	39	54	" " "
1894	38	34	48	52	65	73	78	73	71	57	43	38	56	" " "
1895	31	26	41	53	62	74	73	77	72	53	47	39	54	" " "
1896	34	36	38	57	69	71	78	76	68	55	51	36	56	" " "
1897	32	37	45	53	63	70	77	74	69	58	46	39	55	" " "
1898	37	35	49	51	64	74	79	77	71	58	45	36	56	" " "
1899	33	28	42	54	......	......	......	......	......	......	......	......	....	" " "
Averages	33	35	42	53	63	73	77	75	68	56	45	36	55	‡ A year has been considered abnormally warm or cold when its temperature is as much as 3° above or below the normal annual temperature. Abnormally warm or cold months have been determined as follows: A departure of 4° above or below normal, in June, July and August; of 5° in April, May, September and October; and of 6° in January, February, March, November and December.
Highest mean	43 {1828, 1880, 1890}	47; 1828	51; 1828	60; 1827	71; 1880	79 {1828, 1870}	82 {1868, 1870, 1872}	80 {1870, 1872}	77 {1827, 1881}	63 {1855, 1881}	51 {1849, 1854, 1896}	44 {1881, 1889, 1891}	58 {1828, 1870}	
Lowest mean	23; 1857	26 {1836, 1895}	30; 1843	45; 1821	51; 1843	68 {1836, 1837}	72 {1821, 1891}	70; 1836	62 {1829, 1835}	47; 1836	39 {1820, 1836, 1842, 1848}	25; 1831	50; 1836	
Range	20	21	21	15	20	11	10	10	15	16	12	19	8	
No. of abnormally warm mos. or yrs.‡	8	9	9	6	8	5	6	3	4	6	3	7	2	
No. of abnormally old mos. or years ‡	10	17	4	10	3	7	4	2	5	7	4	7	7	

PERMANENT TEMPERATURE CHANGES.

A careful review of the figures given in the table fails to disclose any facts to support a belief in a permanent increase or decrease in temperature, neither is there traceable any relation between recurring abnormal conditions; that is, it cannot be shown that an abnormally cold or warm month in one year is an index to what may be expected for the same month of the year following. A warm January may be immediately succeeded by several warm Januaries, or they may be alternately warm or cold for several years, and the same is found true of all other months. Also, while the exceptionally warm months have been found for the most part in the earlier period of the records, these extremes have been very nearly equaled in quite recent years. Hence the conclusion is reached that it requires a record of more than eighty-three years to show any permanent change in the conditions of average temperatures, should such exist; while all the evidence obtainable from countries where temperature observations have been continued for a much longer period of time is that no such change has taken place.

PERIODIC CHANGE IN TEMPERATURE.

In investigating a possible periodic change in temperature, it is found by drawing a curve for the 1817-1899 period at Baltimore, that the records start with annual temperatures below normal and continue thus for about eight years. This is followed by a period of irregular oscillations above and below the normal until 1835. A fairly well defined period, during which the annual average temperatures are almost constantly below normal, extends from 1835 to 1858, and a second period, during which they are for the most part above the normal, lasts from 1861 to 1884.

The question of periodic changes of temperature is one that has long engaged the attention of meteorologists. There seems to be a more or less general connection between temperature conditions and certain astronomic intervals of time. The maximum sun spot period of about eleven years has been connected by some with recurring temperature conditions, while the solar period of 26.68 days has been thought to have an influencing effect. A thirty-three year

period has also been established, which, in a rough way, seems related not only to temperatures, but also to various other natural phenomena as far back as records have been made; as for example, the vintage time, melting of glaciers, and the rise and fall of the lake levels in Europe and Asia. Efforts to establish a connection between the weather elements and these various periods have all been ingeniously followed, but as yet the association has not been satisfactorily shown, and only negative results have been achieved.

EXTREMES OF AVERAGE TEMPERATURES FOR THE STATE.

Temperature observations have been made at a few voluntary stations in Maryland for over a quarter of a century, but for the greater part of the state such observations were not general prior to the establishment of the State Weather Service. The longer records furnish the greater extremes of average conditions, but none equal those obtained for Baltimore during the past 83 years. No satisfactory results can be reached through an examination of the shorter series of observations, since no single station has as yet furnished anything approaching the probable range of averages likely to occur in time. The entire range in May and December since 1891—comparing the highest average in the southern counties during the warmest May and December with the lowest average in the mountains during the coldest May and December—fails to give a greater range in the average temperatures for those months than is shown for the single station of Baltimore in its record for eighty-three years. The extreme state range for other months is somewhat greater than that reached at Baltimore, being generally eighteen to twenty-five degrees. The exact figures may be computed from the tables of comparative temperature data given later.

NORMAL DAILY TEMPERATURES.

The progress of normal temperatures from month to month, as already described, furnishes a clue to the rate of daily advance, but does not afford a definite idea of the average time of the occurrence of a stated degree of temperature. It is a matter of value that this

be shown for the months of spring and early summer. Tables of daily normal temperatures have been prepared for selected stations, representing the various climatic divisions, for the months of March, April and May; the results for each fifth day being given in the table below.

ADVENT OF SPRING.

Botanists state that the protoplasmic contents of the vegetable cells find the limits of their activity at 42.8°. When the temperature falls

TABLE OF NORMAL DAILY TEMPERATURES.

	March.							April.							May.						
Day of month....	1	5	10	15	20	25	30	1	5	10	15	20	25	30	1	5	10	15	20	25	30
Sunnyside.............	31	29	36	33	34	37	37	40	41	44	44	47	47	50	51	54	58	54	58	60	61
Cumberland	35	32	39	37	39	40	42	46	47	48	51	53	53	56	56	60	63	61	64	65	67
Green Spring Furnace	35	33	39	37	38	41	41	46	47	50	50	53	53	56	57	60	64	60	63	66	67
Mt. St. Mary's.........	34	32	41	37	39	39	43	45	45	49	52	54	54	58	56	59	63	60	64	65	66
Woodlawn	34	32	39	36	37	40	40	45	46	49	49	52	52	55	57	60	64	60	64	66	67
Baltimore	38	36	43	40	41	44	44	48	49	52	52	55	55	58	59	62	66	62	66	68	69
Washington	38	36	43	40	40	43	44	48	50	51	53	56	55	58	59	62	65	61	67	67	69
Milford, Del...........	39	34	44	41	43	41	45	47	47	51	55	57	56	54	56	57	63	62	66	67	65
Easton.................	39	37	44	41	42	45	45	49	50	53	53	56	56	59	60	63	67	63	67	69	70
Jewell	39	37	44	41	42	45	45	49	50	53	53	56	56	59	60	63	67	63	67	69	70
Mardela Springs	39	37	44	41	42	45	45	48	49	52	52	55	55	58	59	62	66	62	66	68	69
St. Inigoes............	41	39	46	43	44	47	47	51	52	55	55	58	58	61	61	64	68	64	68	70	71

below this point the protoplasm becomes inactive; when the temperature rises and reaches this point the protoplasm awakens, and as it passes above 42.8° the cell begins to grow and multiply. The advent of spring may properly be considered as taking place at the advent of an isotherm one degree higher, or 43.8°.[1]

From the original tables the average date has been obtained on which a daily mean temperature of 44° becomes permanent, and the result is shown in Figure 55, which is intended to represent the average date of the advent of spring in Maryland.

[1] The Advent of Spring. By Mark W. Harrington. Harper's Magazine, 1894.

It will be seen that spring first appears in the extreme southeastern counties, usually about the 7th of March. It advances northward in the next two weeks to an east and west line touching southern Delaware. Within the next four days the line moves northward, east and west, through Prince George's county. Five days later it reaches northern central Maryland, and by the first of April includes most of the state except Garrett county, which does not experience permanent spring conditions until about the middle of April.

There are, of course, many variations from these dates, earlier or

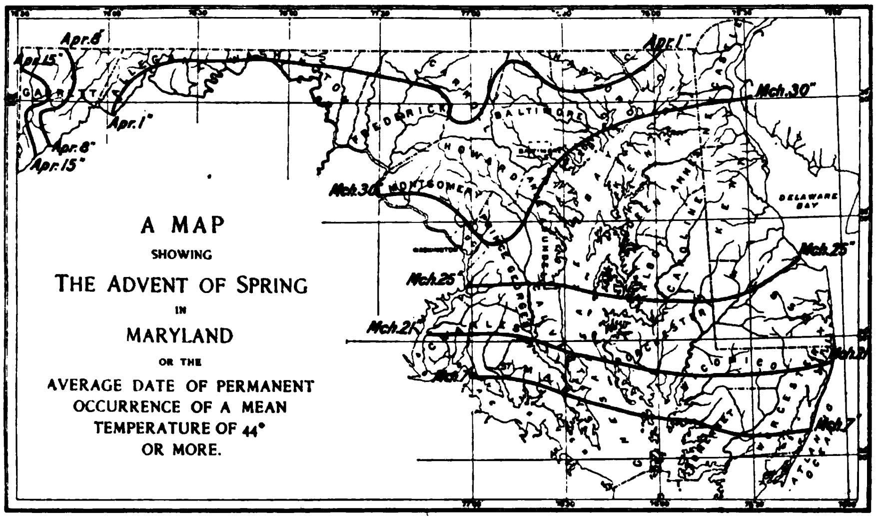

FIG. 55.—The advent of spring.

later. These depend on the persistence of winter conditions, the formation and movement of transient pressure areas over eastern North America, and the shifting of the permanent pressure systems mentioned in the chapter on meteorology.

In Professor Harrington's article, already referred to, it is shown that three warm and three cold waves pass across the United States, alternately, in the month of May; that the first wave, a warm one, reaches Maryland about the 10th, followed by a cold wave about the 14th; this by a second warm wave about the 22d, quickly followed by

a cold wave on the 23d, which in turn is succeeded by a warm wave about the 28th; the final cold wave frequently occurs in early June.

The second cold wave period is the only one well brought out by the figures given in the preceding table. The usual date of its occurrence corresponds somewhat to the Ice Saints' Days of central Europe, which are May 12th, 13th and 14th. These saints were supposed to cause a sudden retreat of spring, after its early advances.

NORMAL TEMPERATURE VARIABILITY.

A condition of interest and value is the normal variability of the mean temperature from day to day. This varies for the different months, although but little for the different parts of the state. The figures below give the normal variability and the greatest and least mean variability at Baltimore for each month during the past twenty-nine years. These figures will apply to the greater portions of the state, since they are not determined so much by latitude and elevation as by the movement of transient pressure areas, which in this respect affect all sections very much alike.

NORMAL TEMPERATURE VARIABILITY AT BALTIMORE, MARYLAND.

	Jan.	Feb.	Mar.	Apr.	May	Jun.	July	Aug.	Sep.	Oct.	Nov.	Dec.
Monthly normal for 29 years...	6.1	6.2	6.0	5.3	4.6	3.8	3.4	3.2	4.0	4.5	5.4	5.5
Greatest monthly average	9.3	7.6	9.0	6.6	5.9	4.8	4.2	3.5	5.1	6.0	6.5	7.0
Least monthly average...	4.3	4.1	3.9	4.3	3.8	2.4	2.2	2.5	2.8	3.2	3.8	3.8

NORMAL MAXIMUM AND MINIMUM TEMPERATURES.

The normal annual maximum temperature for the state is about 63°, or nine degrees above the normal annual temperature. The range above the normal annual temperature is not uniform for all months, being least, about seven or eight degrees in winter, from November to March, and greatest, about nine or ten degrees in the other months; this general fact will appear from an examination of the Table, p. 489, which gives the normal annual maximum temperatures for all stations.

TABLE OF NORMAL MAXIMUM TEMPERATURES.

Records for Five Years or Over.

Stations.	Jan.	Feb.	Mar.	Apr.	May.	Jun.	July.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual.
Baltimore	40 +11 -9	43 +7 -10	49 +9 -6	62 +4 -5	73 +8 -7	82 +3 -5	86 +3 -6	83 +4 -3	77 +8 -5	65 +7 -5	53 +7 -5	44 +7 -9	63
Charlotte Hall	43 +4 -4	44 +4 -9	55 +5 -8	65 +5 -3	....	84 +3 -5	86 +3 -2	87 +3 -4	....	66 +2 -2	56 +8 -4	49 +1 -3	....
Chestertown	39 +4 -2	39 +3 -7	....	....	73 +5 -3	81 +2 -4	84 +2 -3	....	....	63 +8 -2	52 +4 -4	43 +2 -2	....
College Park	41 +3 -5	40 +5 -5	52 +6 -2	63 +3 -2	74 +4 -4	....	....	86 +3 -4	82 +4 -4	....	....	....	...
Darlington	38 +5 -2	40 +2 -7	49 +8 -7	61 +6 -2	72 +5 -3	81 +2 -4	84 +2 -4	84 +5 -4	76 +4 -2	63 +2 -3	52 +6 -3	42 +3 -4	62
Dover, Del	40 +5 -8	42 +2 -9	51 +7 -6	62 +3 -2	72 +6 -2	81 +3 -3	84 +2 -4	83 +2 -4	76 +3 -2	63 +3 -3	53 +6 -3	45 +2 -3	63
Easton	40 +5 -9	43 +2 -7	56 +5 -9	64 +2 -5	74 +3 -2	82 +2 -4	85 +4 -4	85 +2 -3	78 +6 -3	67 +3 -4	56 +5 -4	44 +5 -9	64
Frederick	36 +5 -8	40 +4 -7	49 +7 -5	62 +4 -3	74 +4 -2	83 +3 -3	87 +3 -5	85 +3 -2	78 +4 -4	64 +1 -2	51 +7 -6	42 +2 -4	63
Mardela Springs	41 +5 -8	43 +5 -9	52 +7 -7	61 +4 -2	72 +4 -3	82 +2 -3	84 +1 -4	83 +1 -3	77 +5 -2	66 +2 -3	56 +6 -5	46 +2 -5	64
McDonogh	40 +7 -10	41 +7 -7	50 +8 -8	59 +5 -2	71 +4 -3	79 +3 -4	....	82 +2 -2	75 +3 -1	64 +2 -3	54 +5 -2	44 +1 -3	...
Milford, Del	44 +3 -3	44 +4 -6	55 +4 -5	64 +3 -2	74 +5 -3	82 +4 -2	86 +2 -1	86 +6 -2	80 +4 -5	68 +2 -2	57 +7 -3	49 +2 -2	66
Millsboro, Del	42 +6 -8	44 +3 -9	54 +5 -4	63 +2 -5	73 +5 -3	81 +3 -3	85 +2 -2	84 +3 -3	78 +3 -2	65 +3 -2	57 +7 -6	48 +2 -4	64
Mt. St. Mary's	37 +6 -9	39 +1 -8	49 +7 -8	61 +4 -4	71 +2 -1	80 +3 -3	85 +3 -3	....	... .	64 +3 -4	51 +7 -3	41 +4 -2	....
Seaford, Del	42 +6 -7	44 +3 -9	54 +7 -6	65 +3 -5	74 +3 -3	82 +4 -5	85 +1 -4	85 +2 -5	78 +4 -2	66 +2 -3	56 +4 -4	47 +4 -5	65
Solomon's	41 +7 -7	43 +2 -7	52 +6 -4	62 +2 -2	74 +5 -3	83 +2 -3	86 +2 -2	86 +4 -2	80 +5 -4	68 +1 -2	56 +6 -3	46 +4 -4	65
Sunnyside	35 +4 -4	34 +4 -9	46 +8 -11	56 +7 -5	69 +5 -5	....	79 +1 -4	....	73 +2 -1	61 +5 -5	47 +5 -5	39 +2 -3	....
Washington	41 +11 -8	44 +7 -10	50 +9 -7	63 +5 -7	75 +7 -6	83 +4 -5	86 +5 -6	84 +5 -4	78 +11 -6	66 +7 -5	53 +7 -6	44 +10 -10	64
Woodstock	40 +4 -3	41 +3 -7	51 +6 -6	62 +4 -2	74 +4 -3	82 +2 -4	....	83 +2 -2	75 +4 -2	63 +2 -2	53 +6 -3	44 +1 -2	....

NOTE.—For each station is given (1) the normal, (2) the greatest departure above the normal, and (3) the greatest departure below the normal, for the entire period of observation.

TABLE OF NORMAL MINIMUM TEMPERATURES.

Records for Five Years or Over.

STATIONS.	Jan.	Feb.	Mar.	Apr.	May.	Jun.	July.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual.
Baltimore	27 +9 -9	29 +7 -9	34 +7 -6	44 +6 -4	56 +5 -5	64 +3 -3	69 +5 -5	67 +3 -2	61 +9 -5	49 +7 -6	39 +3 -3	31 +5 -12	48
Charlotte Hall	26 +4 -4	24 +3 -10	34 +4 -6	43 +2 -3	....	62 +2 -2	66 +2 -4	65 +2 -1	....	46 +4 -8	38 +6 -2	29 +3 -2	....
Chestertown	26 +5 -3	25 +4 -9	....	....	54 +4 -2	61 +2 -2	67 +2	....	....	47 +4 -6	38 +4 -3	29 +3 -3	....
College Park	25 +7 -5	23 +4 -8	33 +3 -6	42 +3 -3	53 +2 -4	....	... .	62 +5 -2	57 +2 -3	....	....	....	....
Darlington	24 +4 -3	23 +5 -9	32 +7 -6	41 +5 -1	52 +5 -3	61 +2 -3	66 +4 -5	63 +3 -2	57 +3 -3	44 +4 -6	36 +5 -3	26 +3 -4	44
Dover, Del.	25 +6 -9	26 +3 -9	34 +5 -4	44 +3 -4	54 +5 -2	64 +3 -3	67 +2 -3	66 +2 -2	60 +3 -3	46 +4 -3	38 +4 -3	30 +3 -4	46
Easton	25 +7 -8	27 +3 -8	35 +7 -5	43 +3 -3	54 +4 -2	62 +7 -3	67 +1 -4	65 +3 -1	59 +3 -3	46 +4 -6	37 +4 -4	29 +3 -4	46
Frederick	24 +6 -7	26 +2 -9	33 +8 -5	42 +4 -2	53 +2 -3	62 +5 -4	66 +3 -5	63 +4 -2	57 +4 -2	45 +4 -7	36 +5 -2	28 +2 -2	45
Mardela Springs	25 +6 -11	27 +2 -10	34 +6 -4	43 +4 -3	54 +4 -3	64 +3 -3	67 +2 -3	65 +2 -3	60 +4 -3	46 +3 -4	38 +4 -4	29 +4 -4	46
McDonogh	23 +7 -8	25 +3 -9	34 +7 -6	44 +6 -2	55 +5 -4	64 +4 -2	....	....	59 +5 -4	46 +5 -5	37 +6 -4	29 +2 -5	....
Milford, Del.	27 +5 -3	26 +3 -8	36 +5 -6	43 +3 -1	56 +10 -4	63 +1 -1	68 +4 -4	66 +4 -3	61 +3 -2	48 +4 -7	39 +5 -4	30 +3 -4	47
Millsboro, Del.	24 +6 -12	26 +4 -10	34 +4 -5	42 +3 -2	53 +4 -3	62 +1 -2	67 +2 -4	65 +4 -2	59 +3 -2	46 +5 -7	39 +5 -5	30 +2 -4	46
Mt. St. Mary's	21 +5 -7	24 +2 -4	30 +8 -4	42 +4 -3	52 +4 -2	62 +4 -4	68 +6 -5	....	....	45 +2 -2	34 +5 -5	25 +2 -2	....
Seaford, Del.	25 +6 -11	26 +3 -10	33 +7 -4	43 +2 -2	53 +4 -3	62 +4 -2	66 +4 -3	65 +2 -3	59 +3 -4	45 +6 -4	37 +5 -3	28 +4 -3	45
Solomon's	28 +6 -10	28 +2 -9	35 +6 -8	45 +2 -4	56 +5 -2	66 +4 -2	70 +1 -3	70 +2 -2	64 +3 -2	50 +4 -4	41 +4 -2	32 +2 -2	49
Sunnyside	18 +6 -4	16 +5 -11	26 +8 -8	35 +5 -4	44 +5 -5	....	56 +2 -4	....	48 +3 -3	35 +2 -6	28 +4 -3	22 +1 -2	....
Washington	26 +10 -6	28 +8 -10	33 +7 -6	43 +7 -5	54 +5 -3	63 +4 -4	68 +5 -5	66 +5 -3	59 +9 -4	47 +7 -6	37 +4 -4	29 +7 -9	46
Woodstock	23 +4 -5	23 +4 -9	31 +6 -6	41 +4 -2	52 +4 -4	61 +5 -5	....	61 +6 -2	55 +5 -2	41 +5 -5	34 +3 -4	26 +3 -5	....

NOTE.—For each station is given (1) the normal, (2) the greatest departure above the normal, and (3) the greatest departure below the normal, for the entire period of observation.

The distribution of normal maximum temperatures within the state limits is illustrated in Figure 56, which is prepared on the same plan as the one used for showing the mean temperature distribution. As with the former diagram, the greatest departures below the normal

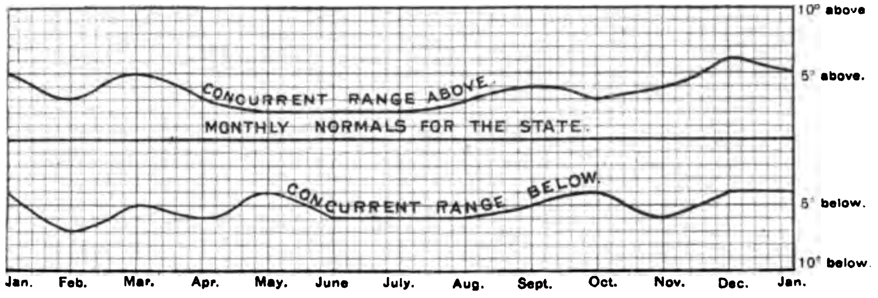

FIG. 56.—The concurrent range of monthly normal maximum temperatures in Maryland.

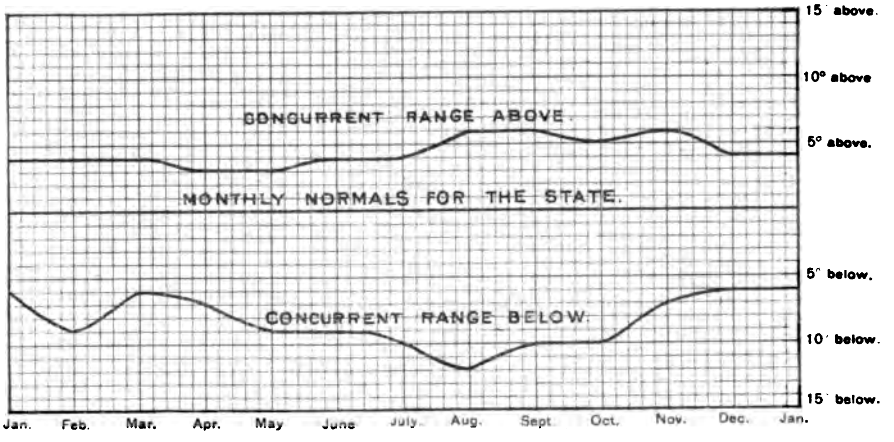

FIG. 57.—The concurrent range of monthly normal minimum temperatures in Maryland.

maximum temperatures for the state are found in the mountains, and the greatest departures above in the south and southeast; and in summer the departures below the normal in the mountains are greater than the departures above in the southeast.

The normal annual minimum temperature for the state at large

is 45°, or nine degrees below the normal annual temperature. The general statement respecting the local and monthly distribution of normal maximum temperatures is also true of the normal minimum temperatures; that is, the range of the normal minimum temperatures below the state normal temperatures is least in winter and greatest in summer, and the greatest *local* departures *above* the normal minima are found in the southern counties and the greatest *below* in the mountains.

The general plan adopted for illustrating this distribution is fol-

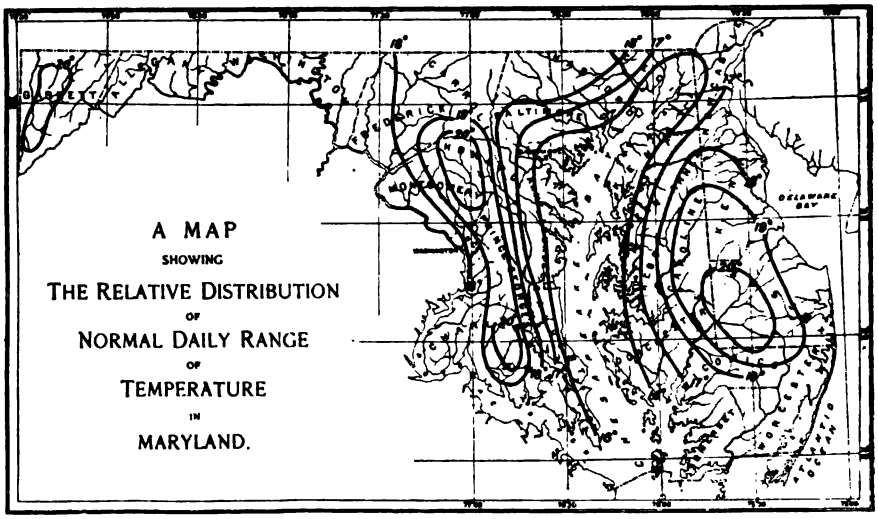

FIG. 58.—Relative distribution of normal daily range of temperatures.

lowed in Figure 57, which shows for the normal minima a greater range as compared with the state normals, than found for the normal maxima; especially is this true of the mountain records, which furnish a minus departure as great as twelve degrees in August, as compared with the state normal minimum for that month. It will thus be seen that terrestrial radiation plays an important part in reducing the temperatures in the higher elevations, being so decided in summer as to cause unusually low minima as compared with those found along the lowlands and water areas. The accompanying table gives the normal monthly and annual minimum temperatures for all stations.

A fact noticed in the study of normal maximum and minimum temperatures is that, throughout, the marked departures are features of minimum rather than maximum conditions; in other words, the determining temperature peculiarities of a section or locality is a function of the minimum and not of the maximum temperature.

NORMAL RANGE OF TEMPERATURE.

The normal range of temperature is naturally the sum of the normal departures of the maximum and minimum from the normal temperature for the month, season or year. The annual normal range is therefore 18°, and the monthly and local distribution of the normal range must agree with the statements already made respecting normal extremes. That is, it is greatest in the summer, and least in the winter months; and also greatest at elevated stations, and least at stations near the water areas. The geographical distribution is brought out in Figure 58, which, although incomplete through lack of data, shows a normal daily temperature range of 16° along the shore, increasing to 20° in the interior land areas and over the mountain elevations. The temperature values given on the chart are averages for the entire year; they would vary somewhat for the different months, but there would be little if any change in the geographical location of the lines.

The following table gives the mean daily range of temperature at the stations named:

MEAN DAILY RANGE OF TEMPERATURE.

STATIONS.	Jan.	Feb.	Mar.	Apr.	May.	Jun.	July.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual.
Baltimore	13	14	15	18	17	18	17	16	16	16	14	13	16
Charlotte Hall	17	20	21	22	....	22	20	22	....	20	18	20	20 ?
Chestertown	13	14	....	....	19	20	17	....	....	16	14	14	16 ?
College Park	16	17	19	21	21	....	....	24	25	....	....	....	20 ?
Darlington	14	17	17	20	20	20	18	21	19	19	16	16	18
Dover, Del	15	16	17	18	18	17	17	17	16	17	15	15	16
Easton	15	16	21	21	20	20	18	20	19	21	17	15	19
Frederick	12	14	16	20	21	21	21	22	21	19	15	14	18
Mardela Springs	16	16	18	18	18	18	17	18	17	20	18	17	18
McDonogh	17	16	16	15	16	15	....	....	16	18	17	15	16 ?
Milford, Del	17	18	19	21	18	19	18	20	19	20	18	19	19
Millsboro, Del	18	18	20	21	20	19	18	19	19	19	18	18	19
Mt. St. Mary's	16	15	19	19	19	18	17	....	....	19	17	16	18 ?
Seaford, Del	17	18	21	22	21	20	19	20	19	21	19	19	20
Solomon's	13	15	17	17	18	17	16	16	16	18	15	14	16
Sunnyside	17	18	20	21	15	....	23	....	25	26	19	17	20 ?
Washington	15	16	17	20	21	20	18	18	19	19	16	15	18
Woodstock	17	18	20	21	22	21	....	22	20	22	19	18	20 ?
Average	15	16	18	20	19	19	18	20	19	19	17	16	18

ABSOLUTE EXTREMES OF TEMPERATURE.

In the following table, which gives the absolute maximum temperatures for the various stations, the records are for the most part for seven years only, although for Baltimore and Washington the extreme conditions for the past thirty years are shown. There is no station in the table that has in the past seven years an absolute maxi-

HIGHEST RECORDED TEMPERATURES.

MAINLY FROM RECORDS FOR FIVE YEARS OR OVER.

STATIONS.	Jan.	Feb.	Mar.	Apr.	May.	Jun.	July.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual.
Annapolis	61	63	68	87	94	95	97	94	98	85	69	64	98
Bachman's Valley	60	58	76	90	95	100	103	98	95	84	75	64	103
Baltimore	73	78	82	94	96	98	104	98	101	90	78	73	104
Charlotte Hall	66	70	83	97	95	100	102	99	100	88	78	70	102
Chestertown	63	61	79	87	92	94	97	93	90	83	75	65	97
College Park	62	68	82	92	94	100	105	98	101	88	78	69	105
Cumberland	70	66	84	94	98	101	103	101	97	87	86	68	103
Darlington	65	62	78	94	94	96	98	97	94	85	74	69	98
Deer Park	61	61	75	84	93	99	94	91	90	80	70	65	99
Denton	62	70	82	97	98	101	102	97	98	82	80	72	102
Easton	65	64	82	93	93	96	101	98	96	87	77	66	101
Ellicott City	60	65	78	88	89	96	101	93	95	87	76	66	101
Frederick	64	63	75	92	95	99	104	99	96	86	75	66	104
Hagerstown	62	62	82	92	98	98	98	100	95	88	77	66	100
Jewell	64	66	80	94	95	99	99	97	95	83	78	68	99
Laurel	64	61	80	94	94	99	104	98	100	90	77	67	104
Mardela Springs	70	67	80	92	93	96	98	100	95	88	77	67	100
McDonogh	64	59	75	90	91	94	95	94	91	82	74	68	95
Milford, Del	66	66	84	97	96	99	99	99	99	90	78	71	99
Millsboro, Del	65	68	82	99	97	98	98	98	95	87	78	68	99
Mt. St. Mary's	61	62	78	93	90	96	102	96	95	88	74	65	102
Newark, Del	56	61	73	92	92	96	98	98	97	86	75	63	98
New Market	62	61	79	93	93	99	105	98	96	85	83	65	105
Pocomoke City	69	70	81	93	96	99	101	100	96	91	81	74	101
Princess Anne	68	66	76	93	93	96	95	98	96	84	78	68	98
Seaford, Del	65	66	82	95	94	98	100	97	95	84	75	68	100
Solomon's	66	67	82	88	100	99	99	98	98	89	77	65	100
Sunnyside	61	64	75	87	90	92	93	90	91	82	73	65	93
Van Bibber	63	62	72	91	96	95	98	96	95	87	71	68	98
Woodstock	64	61	78	93	95	98	102	97	94	85	76	66	102
Westernport	65	66	81	92	96	102	107	99	98	88	78	65	107
Westminster	60	62	82	94	99	99	103	102	98	90	74	66	103
Wilmington, Del.	55	62	74	97	98	102	101	103	98	84	76	66	103
Washington	76	78	83	93	96	102	103	101	104	92	80	73	104
Extremes for each month	76	78	84	99	100	102	109*	103	104	92	86	74	109

* At Boettcherville, near Cumberland.

mum temperature below 93°, which is the record for Sunnyside, the most elevated of all the points of observation. The highest temperature recorded since 1891 within the state limits was 109° at Boettcherville.

The extremes of temperature generally recorded for the state occurred during the unusually hot wave of July 1st to 4th, 1898, during

which temperatures of 93° to over 100° were recorded at every reporting station in Maryland. It will thus be seen that the differences in elevation found in Maryland are not sufficiently great to cause a large range in the absolute maximum temperatures, nor do conditions of latitude and water surroundings strongly influence this feature, although none of these are without modifying effects.

The absolute minimum temperatures for the entire state are deter-

LOWEST RECORDED TEMPERATURES.

MAINLY FROM RECORDS FOR FIVE YEARS OR OVER.

STATION.	Jan.	Feb.	Mar.	Apr.	May.	Jun.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
Annapolis	5	−6	....	24	40	..	58	52	40	33	25	....	−6
Bachman's Valley	−11	−23	−8	17	31	36	46	44	35	20	17	0	−23
Baltimore	−6	−7	5	24	34	47	55	51	39	30	15	−3	−7
Charlotte Hall	−1	....	0	25	37	41	49	52	40	23	18	5	−1
Chestertown	5	−9	16	25	37	43	54	51	41	30	22	9	−9
College Park	−2	−16	10	24	35	38	48	44	34	26	16	4	−16
Cumberland	−7	−12	6	25	33	45	52	50	35	22	14	2	−12
Darlington	−8	−12	8	20	38	42	51	50	40	26	18	3	−12
Deer Park	−23	−25	−13	6	20	30	32	31	22	4	−6	−20	−25
Denton	−17	−14	15	25	37	43	50	50	43	27	21	9	−17
Easton	−1	−15	15	26	38	40	52	50	38	28	21	12	−15
Ellicott City	−8	−8	18	21	32	48	51	53	45	28	19	6	−8
Frederick	−7	−10	0	25	33	39	50	45	37	25	19	0	−10
Hagerstown	−8	−14	1	20	34	42	49	48	38	26	24	1	−14
Jewell	1	−14	11	23	38	45	53	50	41	28	21	8	−14
Laurel	−4	−18	7	23	34	45	49	46	35	21	22	6	−18
Mardela Springs	−10	....	15	24	37	42	51	50	39	26	18	11	−10
McDonogh	−3	−11	5	26	40	45	51	54	42	32	19	10	−11
Milford, Del	6	−12	17	26	38	49	53	53	39	30	21	10	−12
Millsboro, Del	−17	−10	12	22	35	40	51	50	37	29	18	6	−17
Mt. St. Mary's	−14	−15	11	21	37	42	51	50	40	22	13	6	−15
Newark, Del	−1	−12	12	21	37	42	50	49	36	27	19	6	−12
New Market	−4	−14	5	21	33	45	52	49	38	25	16	3	−14
Pocomoke City	8	−4	18	27	40	46	55	55	42	33	21	11	−4
Princess Anne	1	−10	16	22	31	40	51	46	33	23	21	9	−10
Seaford, Del	−5	−11	12	25	36	44	53	51	39	28	20	6	−11
Solomon's	4	−5	18	28	41	49	57	59	46	35	23	11	−5
Sunnyside	−24	−26	−2	8	24	29	33	36	24	10	−4	−17	−26
Van Bibber	−1	−11	9	23	38	43	53	50	41	31	19	10	−11
Washington	−14	−15	4	22	34	43	52	49	38	26	12	−13	−15
Westernport	−8	−13	−8	19	30	36	41	42	28	16	15	−6	−13
Westminster	−7	−16	12	22	34	..	..	..	..	30	19	7	−16
Woodstock	−14	−13	−4	22	34	40	..	45	34	23	15	3	−14
Extremes	−24	−26	−13	6	20	29	32	31	22	4	−6	−20	−26

mined largely by elevation, latitude and water surroundings. The preceding table shows the absolute minima reached at the various stations in the past seven years, except that Washington and Baltimore present figures for the past thirty years. Generally speaking, the absolute minima are not as low along the Bay as immediately inland, nor as low inland as in the mountains. The longer period of observations for Baltimore and Washington furnishes records of lowest tem-

peratures not usually reached by stations with seven-year records and having about the same elevation. In February, however, the variance is not great, owing to the fact that the table includes the record of minimum temperatures that prevailed during the extreme cold of February, 1899, which exceeded any known records for the state for that month. The various climatic districts differ greatly in their record of absolute minima. The most interesting fact observed from the table is that a lowest temperature of 32° or below has been recorded in the mountains of Garrett county *in every month in the year.* It has already been seen that, with regard to the maxima generally recorded elsewhere in the state, the mountains do not show this great variance; hence the general rule is again strongly confirmed, that the characteristic climatic feature of a section, as regards temperature, is determined by how low the temperature falls, rather than by the highest record obtained; a fact which has been recognized generally by meteorologists. In the United States all Weather Bureau stations with lengthy records, except a few of high elevation or situated on the border of large water areas, have recorded temperatures of 100° or above; whereas the absolute minima are far from being so uniform, ranging from 20° and 30° above zero to over 60° below zero.

HOT WAVES OF SUMMER.

The heated terms in Maryland are confined principally to July, August, late June and early September. Usually they are of short duration, and their extreme effects are mitigated near the shore by water influences, and in the mountains by the invigorating low night temperatures that prevail. Considerable personal discomfort is felt during their prevalence over the interior land areas not highly elevated, and actual suffering ensues in the larger cities. The protracted heated terms are usually connected with periods of drought. As already explained under the heading of Weather Types, their occurrence is generally due to the persistent location of an area of high pressure over the South Atlantic states. The most noteworthy hot waves of the past seven years are those of August 5-13, 1896, and July 1-4, 1898. In early Sepember the heat is frequently oppressive, but later in that month the cool nights afford relief.

The Table below gives the number of days that the temperature has been above 90°, 95°, and 100° at Baltimore since 1873. It furnishes a partial index to the frequency of warm periods, although the several occurrences of a stated temperature in a month are usually embraced under one or two hot spells.

TABLE SHOWING SUMMER HEAT AT BALTIMORE, MARYLAND.

Year.	No. Days Maximum Temperature was above 90°.						No. Days Max. Temp. was above 95°.					No. Days above 100°.		
	Apr.	May	Jun.	July	Aug.	Sep.	May	Jun.	July.	Aug.	Sep.	July	Aug.	Sep.
1873....	0	0	2	12	2	1	0	0	2	2	0	0	0	0
1874....	0	0	7	7	3	0	0	3	1	0	0	0	0	0
1875....	0	0	6	5	0	1	0	3	1	2	0	0	0	0
1876....	0	0	3	15	0	0	0	0	6	0	0	0	0	0
1877....	0	2	3	8	2	0	0	0	0	0	0	0	0	0
1878....	0	0	1	15	2	0	0	0	2	0	0	0	0	0
1879....	0	1	3	8	2	0	0	0	2	0	0	0	0	0
1880....	0	4	8	6	1	0	0	0	2	0	0	0	0	0
1881....	0	3	2	8	7	3	0	0	2	1	1	0	0	1
1882....	0	0	3	6	0	0	0	1	1	0	0	0	0	0
1883....	0	0	0	7	2	0	0	0	1	0	0	0	0	0
1884....	0	0	4	3	3	2	0	0	0	0	0	0	0	0
1885....	0	0	3	15	2	0	0	0	4	0	0	0	0	0
1886....	0	0	0	2	1	1	0	0	0	0	0	0	0	0
1887....	0	0	2	8	2	0	0	0	4	0	0	2	0	0
1888....	0	0	8	2	8	0	0	0	0	1	0	0	0	0
1889....	0	1	1	3	0	0	0	0	0	0	0	0	0	0
1890....	0	0	4	7	2	0	0	0	2	0	0	0	0	0
1891....	0	0	5	0	5	1	0	0	0	0	0	0	0	0
1892....	0	0	5	9	3	0	0	0	4	0	0	0	0	0
1893....	0	0	4	8	0	0	0	1	1	0	0	0	0	0
1894....	0	0	6	10	1	2	0	2	3	0	0	0	0	0
1895....	0	2	5	4	9	6	0	2	1	2	3	0	0	0
1896....	2	5	2	7	9	3	1	0	1	4	0	1	0	0
1897....	0	0	2	2	0	4	0	0	0	0	0	0	0	0
1898....	0	1	4	9	8	7	0	1	4	0	2	2	0	0
1899....	0	....	....	....	....	....	....	....	....	....	....	....	....	....
Total.	2	19	93	186	74	31	1	13	44	12	6	5	0	1

COLD WAVES OF WINTER.

The conditions that usually produce cold waves in winter have already been described and illustrated under the heading of Weather Types. These conditions cause decided falls in temperature generally throughout the state, but at certain seasons extremely low tempera-

tures result in the mountains, while along the Bay and throughout the interior the lowest temperatures are not especially cold; for this

THE COLD PERIOD OF FEBRUARY 9-14, 1899.

Station.	Lowest Temperature.		Lowest Mean Temperature.	
	Degree.	Date.	Degree.	Date.
Western Maryland.				
Sunnyside	−26	10	−16.5	10
Deer Park	−25	11	−15.5	10
Cumberland	−12	10	− 2.5	10
Green Spring Furnace	−14	11	− 4.0	10
Hagerstown	−14	10	− 5.0	10
Northern-Central Maryland.				
Mount St. Mary's	−15	10	− 7.0	10
Westminster	−16	10	− 8.5	10
Darlington	−12	11	− 4.5	11
Frederick	−10	11	− 1.5	10
Baltimore	− 7	10	− 2.0	10
Southern Maryland.				
Laurel	−18	11	− 3.0	10 and 11
Annapolis	− 6	10	− 1.5	10
Washington	−15	11	− 2.0	10
Jewell	−14	10	− 3.0	10
Solomon's	− 5	10	1.0	10
Eastern Maryland.				
Chestertown	− 9	11	− 2.5	10
Easton	−15	11	− 1.5	10
Mardela Springs	−10	10	0.5	10
Princess Anne	−10	15	1.0	10
Pocomoke City	− 4	10	3.5	10
Delaware.				
Newark	−12	11	− 4.5	10
Wyoming	−14	11	− 3.0	10
Milford	−12	10	− 7.5	10
Millsboro	−10	10	− 3.0	11
Seaford	−11	11	1.0	10

reason no attempt has been made to determine the cold wave frequency for the entire state. Roughly speaking, there are about eight or ten well-defined cold waves each year for this part of the country.

The most marked cold periods of the past seven years were those

of January 10th-16th, 1893, February 5th-9th, 1895, and February 9th-14th, 1899. The following extract regarding the cold wave of January, 1893, is taken from the Maryland Weather Service report for that month:

> "The month of January, 1893, will long be remembered for its accompaniment of extremely cold weather, which is well known not to have been at all local in character, nearly every section of the country having been invaded by a temperature very low in comparison with previous records. Probably not since January, 1856, has there been experienced in Maryland, the District of Columbia, and Delaware such a protracted period of severe weather. It is certain that not during the life of the Weather Bureau, which came into existence in 1870, has anything approaching a parallel been experienced. There have been lower temperatures in previous years, but they endured for a day or two only, being quickly succeeded by comparatively warm weather; the mean of several days, or of an entire month, places the recent frigid period far in the lead."

The severe cold wave of February 9th-14th, 1899, broke all previous records, and, with its accompanying features of high winds and heavy snowfall, formed in all probability one of the most remarkable weather periods ever experienced in Maryland. The lowest temperatures were generally recorded on the 10th and 11th, although at a few places still lower temperatures were felt a day or two later. The snow depth throughout the state on the night of the 13th was about three feet in sheltered places, and the drifts were from ten to twenty feet deep. The highways of travel were blocked or greatly impeded for a week, and even railroad traffic was suspended for over two days. Thick ice in the harbor entirely closed navigation for several days, and hampered it materially for about a week. The Table on p. 498 gives the extreme cold and the coldest day for this period at twenty-five selected stations, representing all parts of Maryland and Delaware.

The Table of winter cold following gives the number of days that the maximum temperature has been below 32°, the mean temperature below 14°, and the minimum temperature below zero, at Baltimore since 1873. A fact of interest disclosed by this table is that February leads the other months of winter in the frequency of extremely low temperature periods.

WINTER COLD AT BALTIMORE, MARYLAND.

Year.	No. Days with Maximum Temperature below 32°.					No. Days Mean Temp. below 14°.			No. Days Minimum Temp. below Zero.		
	Nov.	Dec.	Jan.	Feb.	Mar.	Dec.	Jan.	Feb.	Dec.	Jan.	Feb.
1873....	0	0	3	1	2	0	1	2	0	1	0
1874....	0	0	4	1	1	0	0	0	0	0	0
1875....	1	3	9	10	0	0	1	2	0	1	0
1876....	0	11	2	2	0	1	0	0	0	0	0
1877....	0	0	7	0	2	0	0	0	0	0	0
1878....	0	7	3	0	0	0	0	0	0	0	0
1879....	1	0	6	2	0	0	1	0	0	0	0
1880....	3	5	0	1	0	3	0	0	2	0	0
1881....	0	0	7	5	0	0	1	1	0	1	0
1882....	0	2	6	0	0	0	0	0	0	0	0
1883....	0	1	8	0	1	0	0	0	0	0	0
1884....	0	2	5	1	1	1	1	0	0	0	0
1885....	0	0	8	8	3	0	0	1	0	0	0
1886....	0	7	11	4	2	0	4	2	0	0	1
1887....	0	4	10	1	0	0	0	0	0	0	0
1888....	0	1	11	3	5	0	0	0	0	0	0
1889....	0	0	0	6	0	0	0	1	0	0	0
1890....	0	2	1	0	4	0	0	0	0	0	0
1891....	1	0	1	2	2	0	0	0	0	0	0
1892....	0	10	9	9	4	0	0	0	0	0	0
1893....	0	2	19	6	1	0	5	0	0	0	0
1894....	0	5	2	5	0	1	0	0	0	0	0
1895....	0	3	10	11	1	0	1	5	0	0	0
1896....	0	5	5	4	0	0	0	2	0	0	0
1897....	0	1	6	1	0	0	1	0	0	0	0
1898....	0	1	3	3	0	0	0	0	0	0	0
1899....	—	—	6	11	0	—	0	5	—	0	2
Total.	6	72	162	97	29	6	16	21	2	3	3

FROSTS.

The formation of frost depends upon the amount of moisture in the air, the velocity of the wind and conditions of cloudiness, as well as the actual degree of temperature experienced. With a quiet state of the atmosphere and a clear sky frosts will occur with a much higher temperature than when the sky is overcast or a fresh to brisk wind prevailing.

As has already been shown in the statements regarding minimum temperatures, frosts are possible in the mountain regions during almost any month of the year. For the greater part of the state the average date of last killing frost in spring occurs between the 5th and

15th of April; while the average date of the first killing frost in fall is between the 5th and 15th of October. Their actual occurrence in any year depends upon the atmospheric disturbances that produce them. An area of high pressure may move in over the state and

KILLING FROSTS IN MARYLAND AND DELAWARE.

Stations.	First in Fall.			Last in Spring.		
	1896.	1897.	1898.	1896.	1897.	1898.
Annapolis	Oct. 26.	....	....	....	Apr. 20.	Apr. 2.
Bachman's Valley	Sep. 24.	Sep. 28.	Oct. 17.	....	May 27.	May 9.
Boettcherville	Oct. 9.	Sep. 28.	Oct. 28.	....	....	....
Charlotte Hall	....	Nov. 13.	....	....	Apr. 21.	Apr. 6.
Cherryfields	....	Nov. 13.	Nov. 25.	....	Apr. 20.	....
Chestertown	....	Oct. 18.	Oct. 28.	....	....	....
Cumberland	Oct. 10.	....	....	....	....	....
Darlington	Oct. 8.	Oct. 18.	....	....	....	....
Dover, Del.	Oct. 25.	....	....	Apr. 9.	....	....
Easton	....	Nov. 18.	....	....	Apr. 20.	....
Ellicott City	....	Nov. 13.	Oct. 24.	....	Apr. 20.	....
Fallston	Oct. 8.	Oct. 18.	....	....	Apr. 21.	Apr. 8.
Flintstone	Oct. 1.	Sep. 21.	....	Apr. 9.	Apr. 21.	....
Grantsville	....	Sep. 21.	Oct. 13.	....	May 30.	May 9.
Green Spring Furnace	Oct. 12.	Oct. 18.	Oct. 28.	....	Apr. 21.	Apr. 6.
Jewell	Oct. 19.	Nov. 13.	Oct. 28.	....	Apr. 20.	Apr. 6.
Laurel	....	Oct. 18.	Oct. 28.	....	Apr. 13.	Apr. 4.
Mardela Springs	Oct. 9.	Sep. 29.	Oct. 16.	Apr. 11.	Apr. 22.	Apr. 7.
Milford, Del.	....	....	....	....	Apr. 21.	....
Millsboro, Del.	Oct. 8.	Oct. 31.	....	....	Apr. 21.	Apr. 28.
Mt. St. Mary's	Oct. 22.	Nov. 14.	Oct. 28.	....	Apr. 21.	....
Newark, Del.	Oct. 9.	Oct. 18.	Oct. 28.	Apr. 9.	Apr. 21.	....
New Market	....	Nov. 14.	Oct. 24.	....	....	May 9.
Pocomoke City	Oct. 22.	....	....	Apr. 9.	Apr. 21.	Apr. 4.
Princess Anne	Sep. 24.	Oct. 18.	Oct. 17.	Apr. 11.	May 9.	Apr. 12.
Seaford, Del.	Oct. 9.	Oct. 18.	Oct. 28.	May 8.	Apr. 21.	Apr. 4.
Sharpsburg	Sep. 24.	Sep. 21.	Oct. 17.	....	Apr. 21.	Apr. 9.
Smithsburg	....	Nov. 25.	Oct. 24.	....	Apr. 20.	May 9.
Solomon's	....	Nov. 13.	....	....	Apr. 20.	Apr. 28.
Sunnyside	Sep. 22.	Sep. 21.	Sep. 12.	Apr. 9.	May 30.	May 9.
Taneytown	Oct. 9.	Oct. 4.	Oct. 28.	Apr. 23.	Apr. 20.	Apr. 7.
Van Bibber	....	Oct. 18.	....	....	Apr. 20.	....
Wilmington, Del.	Oct. 25.	....	....	Apr. 9.	....	....
Woodstock	Oct. 8.	Oct. 18.	Nov 2.	Apr. 22.	Apr. 20.	....

bring temperatures sufficiently low to cause a killing frost considerably earlier than the average date, especially if the high pressure centers directly over the state, in which case the low temperatures are likely to be accompanied by a clear atmosphere and very light winds

—a combination of circumstances most favorable to frost formation. On the other hand there may be an absence of areas of high pressure, and the formation of frosts would then be postponed until brought about by the recurrence of the natural cold of the season. Killing frosts have occurred in the northern-central counties nearly a month in advance of the average date. A record at Fallston for twelve years furnishes the earliest autumnal date of killing frost on September 10th, while at Woodstock the earliest killing frost on record in thirteen years occurred on September 15th. No great damage results from the occurrence of frosts in the fall owing to the fact that there is very little tender vegetation remaining in the fields, and the more hardy crops are too far advanced to sustain much injury.

The late frosts of spring are the most injurious of all that occur, and considerable apprehension is felt each year by those engaged in agricultural pursuits until the time of their probable occurrence is entirely passed. The longer records at U. S. Weather Bureau stations show that killing frosts have occurred as late in the spring as April 29th at Washington City, and as late as May 3d at Baltimore, while lighter frosts capable of damaging tender vegetation have occurred over the greater part of the agricultural districts as late as the closing week of May; these latter, however, do not inflict any great loss. The Table on p. 501 gives the dates of the first killing frosts in fall and the last killing frosts in spring at stations in Maryland and Delaware for the past three years.

SENSIBLE TEMPERATURES.

The temperatures given heretofore in the discussion and tables are, approximately, true air temperatures. The same air temperatures do not always produce the same sensation of heat upon the human body, being altered in that respect by coincident conditions of wind movement and the humidity of the atmosphere. By the use of a dry-bulb and a wet-bulb thermometer—the latter being one whose bulb is covered with a moist wrapping—two different degrees of temperature are obtained, the extent of the difference depending upon the rapidity with which evaporation takes place at the time the observation is made. The evaporation from the wetted surfaces causes the wet-bulb

thermometer to read somewhat lower than the dry-bulb thermometer, and considerably lower when the air is comparatively dry. The same conditions of slow or rapid evaporation are taking place on the exposed portions of the body, so that the wet-bulb, or sensible, temperatures represent more accurately the physiological effects of a given degree of heat than do the true air temperatures as given by the dry-bulb thermometer. The table below furnishes in comparative form the average air temperatures and the average sensible temperatures for Baltimore for the past 28 years:

	Jan.	Feb.	Mar.	Apr.	May.	Jun.	July.	Aug.	Sep.	Oct.	Nov.	Dec.	Yr.
Air temp......	33	35	41	53	63	73	77	75	68	56	45	36	55
Sensible temp.	31	31	36	46	56	65	68	68	63	51	41	34	49

COMPARISONS OF TEMPERATURE.

The tables of comparative data, pp. 504-509, furnish a summary for Maryland and Delaware for each month for the past seven years, and form a general history of the average and extreme temperature conditions that have occurred during that period.

The tables on page 510 extend the field of comparison into other parts of the United States and the world. The first table presents records for January, July and the year, at stations situated on or near the 40th parallel of north latitude, which passes north of Maryland; while the others show stations in various countries that agree with Baltimore in their January, July, or yearly temperatures.

These tables show that great variations in temperature are found along a given parallel, and also that an agreement in temperature between two stations at one season does not indicate a harmonious record throughout the year. It will be seen that the January temperatures for some stations agree with the Baltimore records for January, but that a great difference is found when the July temperatures for the two places are compared; others agree in July but not in January, while others agree in annual temperatures but differ widely in both January and July. Finally, for two stations, even in the same latitude, there may be an entire absence of connection in the temperature features presented. These peculiarities are mainly due—latitude conditions being equal—to the factors of elevation and water surroundings.

COMPARATIVE TEMPERATURE DATA FOR MARYLAND AND DELAWARE.

JANUARY.

YEAR.	TEMPERATURE AVERAGES.											TEMPERATURE EXTREMES.								
	Entire section.	W. Md.	N. C. Md.	S. Md.	E. Md.	Delaware.	Highest local.	Lowest local.	Maximum.	Minimum.	Daily range.	Highest.	Station.	Lowest.	Station.	Absolute range.	Lowest maximum.	Station.	Highest minimum.	Station.
1892	31.8	32.0	30.7	31.0	34.5	32.7	35.0	28.0	39.5	24.4	15.1	70	Mardela Springs. Kirkwood.	0	Boettcherville.	70	52	Cumberland.	12	Baltimore.
1893	22.8	21.2	22.5	25.5	24.3	23.8	27.0	13.1	31.9	16.4	15.5	58	Edgemont. Leonardtown. Cumberland.	—17	Denton. Millsboro.	75	42	Sunnyside.	4	Cambridge.
1894	36.9	34.5	35.8	39.2	38.8	37.6	40.8	30.2	46.3	29.4	16.9	67	Cumberland.	3	Sunnyside.	64	52	Cumberland. Denton.	27	Cambridge.
1895	29.5	24.4	28.7	32.1	34.0	31.6	37.4	21.4	37.6	21.1	16.5	66	Pocomoke City.	—17	Sunnyside.	83	44	Sharpsburg.	16	Pocomoke City.
1896	31.9	29.3	31.9	33.4	33.8	32.1	38.0	25.1	39.5	24.6	14.9	66	Boettcherville.	—13	Deer Park.	79	50	Deer Park. Grantsville.	11	Solomon's. Cambridge.
1897	29.5	26.6	29.0	31.0	32.4	31.7	37.0	22.6	36.8	21.9	14.9	66	Jewell.	—12	Deer Park.	78	54	College Park.	10	Solomon's.
1898	35.5	33.3	34.5	37.3	37.5	37.6	43.0	30.4	42.8	28.0	14.8	72	Grantsville.	— 2	Deer Park.	74	53	Bachman's Valley.	19	Annapolis. Charlotte Hall. Solomon's.
Averages.	31.0	28.8	30.4	32.8	33.6	32.4	....	....	39.2	23.7	15.5	....	....	....	....	....	....	....	....	....

FEBRUARY.

YEAR.	Entire section.	W. Md.	N. C. Md.	S. Md.	E. Md.	Delaware.	Highest local.	Lowest local.	Maximum.	Minimum.	Daily range.	Highest.	Station.	Lowest.	Station.	Absolute range.	Lowest maximum.	Station.	Highest minimum.	Station.
1892	35.4	36.2	34.7	34.7	37.0	35.7	38.0	28.0	43.2	29.1	14.1	64	Cumberland.	— 8	Boettcherville.	72	52	McDonogh. Mt. St. Mary's.	16	Leonardtown.
1893	33.3	30.4	32.5	36.5	36.2	36.2	38.9	24.4	42.3	26.4	15.9	70	Denton.	— 5	Boettcherville.	75	57	Cumberland. Glyndon.	16	Solomon's. Cambridge.
1894	33.7	30.5	33.0	36.9	35.5	35.0	38.6	26.5	42.2	25.6	16.6	68	Millsboro. Charlotte Hall.	—10	Oakland.	78	52	Cumberland. Denton.	15	Benedict. Charlotte Hall. Solomon's.
1895	24.5	20.9	25.0	26.1	26.8	24.7	29.3	15.0	33.4	15.7	17.7	72	Burkittsville.	—18	Deer Park.	90	47	Oakland.	8	Solomon's. Princess Anne.
1896	34.6	31.8	34.4	36.2	36.9	35.8	40.2	26.6	43.1	26.4	16.7	66	Milford. Millsboro. Pocomoke City.	—12	Sunnyside.	78	56	McDonogh. Mt. St. Mary's.	12	Ellicott City. Solomon's.
1897	34.8	32.8	34.2	36.7	36.2	36.0	37.5	29.0	41.4	28.2	13.2	68	Charlotte Hall. Washington.	0	Flintstone.	68	51	Frederick. McDonogh. Newark.	20	Ellicott City. Pocomoke City.
1898	33.7	30.7	32.8	35.6	36.0	36.0	40.4	26.2	42.6	24.6	18.0	70	Pocomoke City. Charlotte Hall.	— 9	Sunnyside.	76	58	Bachman's Valley.	12	Pocomoke City.
Averages.	32.9	30.4	32.4	34.7	34.9	34.2	....	....	41.2	25.1	16.1	....	....	....	....	....	....	....	....	....

COMPARATIVE TEMPERATURE DATA FOR MARYLAND AND DELAWARE.

MARCH.

YEAR.	TEMPERATURE AVERAGES.											TEMPERATURE EXTREMES.									
	Entire section.	W. Md.	N. C. Md.	S. Md.	E. Md.	Delaware.	Highest local.	Lowest local.	Maximum.	Minimum.	Daily range.	Highest.	Station.	Lowest.	Station.	Absolute range.	Lowest maximum.	Station.	Highest minimum.	Station.
1892	37.3	37.8	36.0	37.0	37.3	36.7	40.0	34.0	45.4	29.2	16.2	67	Cumberland.	0	Charlotte Hall.	67	51	Denton.	21	Leonardtown.
1893	39.7	38.5	39.0	42.4	41.7	40.5	44.4	34.0	49.4	31.8	17.6	73	Mardela Springs,	6	Sunnyside.	67	60	Edgemont. Frederick. Glyndon.	19	Cambridge.
1894	46.5	42.9	46.0	48.3	49.6	47.2	51.2	40.6	57.2	35.7	21.5	86	Benedict.	2	Sunnyside.	84	70	Oakland.	23	Easton.
1895	39.8	36.5	39.6	42.3	41.8	40.3	44.4	31.4	49.4	30.3	19.1	74	Washington. Easton.	−7	Deer Park.	81	60	Westernport.	26	La Plata. Bel Alton. Pocomoke City.
1896	36.6	32.7	36.1	38.6	39.7	38.2	43.7	26.4	46.0	27.2	18.8	74	Wilmington.	−13	Deer Park.	87	60	Grantsville. Ellicott City.	21	Cambridge.
1897	44.4	42.5	43.9	45.9	46.1	44.5	50.9	38.0	53.8	35.4	18.4	82	Washington.	12	Deer Park.	70	68	Annapolis.	31	Annapolis.
1898	47.6	45.8	47.2	48.7	47.9	48.2	50.4	42.3	56.6	38.0	18.6	84	Boettcherville. Cumberland.	7	Deer Park.	77	71	Easton.	28	Westminster. Annapolis.
Averages.	41.7	39.5	41.1	43.3	43.4	42.2	....	....	51.1	32.5	18.6	....	....	....	....	....	....	....	....	....

APRIL.

YEAR.	Entire section.	W. Md.	N. C. Md.	S. Md.	E. Md.	Delaware.	Highest local.	Lowest local.	Maximum.	Minimum.	Daily range.	Highest.	Station.	Lowest.	Station.	Absolute range.	Lowest maximum.	Station.	Highest minimum.	Station.
1892	50.0	50.4	50.5	51.6	52.6	51.0	54.0	48.0	59.8	42.1	17.7	87	Cumberland.	23	Boettcherville.	64	74	McDonogh.	32	Baltimore. Solomon's.
1893	52.4	51.0	52.0	55.5	53.9	53.8	58.6	46.2	61.9	44.3	17.6	92	Boettcherville.	22	Sunnyside.	70	75	Mardela Springs.	42	Benedict.
1894	50.8	47.8	50.6	52.8	54.1	51.0	55.2	44.2	60.8	40.8	20.0	84	Charlotte Hall Benedict.	9	Sunnyside.	75	73	Oakland.	32	Solomon's.
1895	52.3	49.7	52.2	54.0	53.9	52.1	58.2	45.0	63.0	42.3	20.7	89	Bel Alton. Hancock. Pope's Creek. Wilmington.	18	Sunnyside.	71	76	Oakland. Grantsville.	35	Solomon's.
1896	55.7	54.0	56.3	56.4	56.0	55.9	59.7	48.4	64.3	45.4	18.9	99	Millsboro.	12	Deer Park.	87	84	Deer Park.	32	Annapolis. Solomon's. Cambridge.
1897	52.1	49.8	52.0	53.6	53.2	52.8	56.8	45.4	62.5	41.5	21.0	94	Taneytown.	15	Sunnyside.	79	78	Sunnyside.	32	Charlotte Hall. Pocomoke City.
1898	49.4	45.8	49.9	51.2	49.9	50.1	53.5	40.6	59.1	39.6	19.5	88	Ocean City.	6	Deer Park.	82	73	Deer Park. Sunnyside. McDonogh.	30	McDonogh.
Averages.	51.8	49.8	51.9	53.6	53.4	52.4	....	....	61.6	42.3	19.3	....	....	....	....	....	....	....	....	....

COMPARATIVE TEMPERATURE DATA FOR MARYLAND AND DELAWARE.

MAY.

YEAR.	TEMPERATURE AVERAGES.											TEMPERATURE EXTREMES.								
	Entire section.	W. Md.	N. C. Md.	S. Md.	E. Md.	Delaware.	Highest local.	Lowest local.	Maximum.	Minimum.	Daily range.	Highest.	Station.	Lowest.	Station.	Absolute range.	Lowest maximum.	Station.	Highest minimum.	Station.
1892	63.1	62.0	63.0	64.2	64.0	62.7	64.8	60.2	72.4	53.6	18.8	90	Seaford.	35	Boettcherville.	55	80	Mc Donogh.	48	New Market.
1893	61.2	59.1	60.7	65.0	63.1	62.0	66.2	53.2	71.8	51.7	20.1	92	Boettcherville. Millsboro.	33	Sunnyside.	59	79	Oakland. Sunnyside.	51	Cambridge.
1894	64.2	61.1	63.9	66.3	65.8	65.1	67.9	55.0	74.4	54.4	20.0	91	Wilmington.	28	Sunnyside.	63	81	Oakland.	47	Mt. St. Mary's. Easton.
1895	61.5	59.3	62.4	62.5	62.2	61.7	65.4	54.0	71.8	51.6	20.2	101	Hancock.	20	Deer Park.	81	86	Oakland.	42	Ellicott City. Solomon's. Pocomoke City.
1896	65.8	65.9	67.5	68.8	68.2	68.0	71.2	61.3	78.0	56.3	21.7	96	Westernport. Baltimore. Van Bibber. Wilmington.	31	Princess Anne.	65	84	Sunnyside.	52	Annapolis.
1897	61.1	58.4	61 5	62.5	61.8	62.2	65.5	51.3	70.9	50.7	20.2	86	Westernport. Solomon's. Flintstone.	27	Deer Park.	59	76	Ellicott City. Sunnyside.	48	Ellicott City.
1898	62.7	62.2	63.5	64.4	61.5	61.7	69.4	58.6	72.4	52.7	19.7	96	Taneytown. Milford.	25	Deer Park. Sunnyside.	71	83	Deer Park. Grantsville. Sunnyside. Port Deposit.	42	Cumberland. Milford.
Averages.	62.8	61.1	63.2	64.8	63.8	63.3	.....	.....	73.1	53.0	20.1	.....	.....	.....	.....	.....	.....	.....	.....	.....

JUNE.

YEAR.	Entire section.	W. Md.	N. C. Md.	S. Md.	E. Md.	Delaware.	Highest local.	Lowest local.	Maximum.	Minimum.	Daily range.	Highest.	Station.	Lowest.	Station.	Absolute range.	Lowest maximum.	Station.	Highest minimum.	Station.
1892	75.3	75.3	75.2	77.1	75.8	74.2	78.7	71.2	83.8	66.9	16.9	98	New Market.	49	Seaford.	49	89	McDonogh.	59	Cumberland.
1893	72 3	70.4	71.6	74.3	73.4	71.8	76.6	65.0	81.5	62.9	18.6	104	Kirkwood.	40	Sunnyside.	64	86	Oakland.	61	Cambridge.
1894	71.9	68.9	72.0	73.8	72.6	73.0	75.6	64.0	82.7	60.9	21.8	104	Benedict.	32	Sunnyside.	72	86	Oakland.	50	Dover.
1895	73.2	70.5	73.7	74.7	73.9	73.9	77.2	65.3	84.1	62.0	22.1	102	Westernport.	37	Deer Park.	65	86	Oldtown.	56	Oldtown. Solomon's.
1896	70.4	68.3	70.1	72.0	71.4	70.8	76.1	63.0	79.7	61.0	18.7	100	Westernport.	32	Deer Park.	68	85	Sunnyside. Deer Park.	63	Annapolis.
1897	68.6	67.8	67.8	70.1	68.4	68.9	72.5	62.1	78.7	58.2	20.5	97	Taneytown.	29	Grantsville. Sunnyside.	68	84	Deer Park.	55	Annapolis.
1898	71.7	69.0	72.1	73.8	72.0	71.5	76.8	60.8	82.8	60.2	22.6	100	Westernport. Bachman's Valley	35	Deer Park.	65	87	Sunnyside.	55	Baltimore. Solomon's.
Averages.	71.9	70.0	71.8	73.7	72.5	72.0	.....	.....	81.9	61.7	20.2	.....	.....	.....	.....	.....	.....	.....	.....	.....

COMPARATIVE TEMPERATURE DATA FOR MARYLAND AND DELAWARE.

JULY.

YEAR.	Temperature Averages. Entire section.	W. Md.	N. C. Md.	S. Md.	E. Md.	Delaware.	Highest local.	Lowest local.	Maximum.	Minimum.	Daily range.	Temperature Extremes. Highest.	Station.	Lowest.	Station.	Absolute range.	Lowest maximum.	Station.	Highest minimum.	Station.
1892	75.8	74.4	75.5	77.6	75.8	76.7	78.9	72.9	85.3	66.2	19.1	102	Kirkwood.	50	Boettcherville.	52	95	McDonogh.	64	Leonardtown.
1893	76.5	73.0	76.3	80.1	77.0	75.6	81.3	67.8	86.2	66.4	19.8	102	Denton.	43	Sunnyside.	59	90	Sunnyside.	67	Cambridge.
1894	75.8	71.5	75.9	78.4	77.4	77.6	82.6	66.0	86.2	64.3	21.9	101	Wilmington.	34	Sunnyside.	67	87	Oakland.	62	Annapolis.
1895	71.4	68.1	71.9	73.1	72.6	73.4	76.8	62.3	81.4	61.5	19.9	102	Westernport.	32	Deer Park.	70	87	Oldtown.	59	Ellicott City.
1896	76.0	73.0	76.5	77.5	76.9	77.2	82.4	68.0	85.2	66.9	18.3	99	Westernport. Wilmington.	40	Sunnyside. Deer Park.	59	86	Deer Park.	68	Annapolis.
1897	75.6	73.3	76.0	77.2	76.4	75.9	78.8	67.6	83.5	66.9	16.6	102	Westernport.	41	Deer Park.	61	88	Chestertown.	64	Annapolis. Solomon's. Pocomoke City.
1898	77.5	75.9	77.9	78.3	77.9	77.5	80.4	69.0	87.6	67.0	20.6	109	Boettch rville.	32	Deer Park.	77	89	Frostburg.	62	Solomon's.
Averages.	75.5	72.7	75.7	77.5	76.3	76.3	....	....	85.1	65.6	19.5	....	....	....	....	....	....	....	....	....

AUGUST.

YEAR.	Temperature Averages. Entire section.	W. Md.	N. C. Md.	S. Md.	E. Md.	Delaware.	Highest local.	Lowest local.	Maximum.	Minimum.	Daily range.	Temperature Extremes. Highest.	Station.	Lowest.	Station.	Absolute range.	Lowest maximum.	Station.	Highest minimum.	Station.
1892	75.9	76.8	74.9	77.5	76.0	76.9	79.7	72.1	85.5	66.5	19.0	101	Cumberland.	56	Edgemont. Boettcherville.	45	92	McDonogh. Mardela Springs. Dover.	63	Solomon's.
1893	73.5	69.2	73.4	75.7	74.9	73.9	79.2	63.6	84.4	64.6	19.8	97	Boettcherville.	44	Oakland. Boettcherville.	53	90	Baltimore. Darlington. Dover. Milford.	63	Cambridge.
1894	71.4	68.2	71.6	73.9	72.4	72.0	75.8	63.8	81.9	62.0	19 9	97	Darlington.	39	Sunnyside.	58	84	Oakland.	60	Solomon's.
1895	75.7	72.6	75.8	77.0	77.8	77.1	80.7	64.4	87.2	64.0	23.2	102	Westminster.	81	Deer Park.	71	86	Oakland.	60	Ellicott City. Solomon's. Pocomoke City.
1896	74.6	71.3	74.8	77.1	75.1	75.7	86.0	65.6	84.8	63.6	21.2	103	Wilmington.	34	Deer Park.	69	90	Sunnyside.	59	Solomon's.
1897	71.8	68.4	71.8	74.1	73.6	73.5	77.7	62.7	82.0	61.6	20.4	95	Westernport. Pocomoke City.	39	Deer Park. Sunnyside.	56	84	Smithsburg.	63	Annapolis. Solomon's.
1898	75.9	73.1	75.2	77.6	77.1	76.7	80.3	66.5	84.7	67.0	17.7	98	Boettcherville. Laurel.	46	Deer Park.	52	88	Sunnyside. Fallston.	66	Solomon's.
Averages.	74.1	71.4	73.9	76.1	75.3	75.1	....	....	84.4	64.2	20.2	....	....	....	....	....	....	....	....	....

COMPARATIVE TEMPERATURE DATA FOR MARYLAND AND DELAWARE.

SEPTEMBER.

Year.	Temperature Averages. Entire section.	W. Md.	N. C. Md.	S. Md.	E. Md.	Delaware.	Highest local.	Lowest local.	Maximum.	Minimum.	Daily range.	Temperature Extremes. Highest.	Station.	Lowest.	Station.	Absolute range.	Lowest maximum.	Station.	Highest minimum.	Station.
1892	65.9	66.0	65.0	64.0	66.2	67.5	69.5	63.2	75.9	56.3	19.6	98	Edgemont.	40	Boettcherville.	58	83	Cumberland.	54	Solomon's.
1893	65.3	62.3	64.1	67.9	67.4	66.6	71.2	58.0	74.6	56.7	17.9	93	Cambridge.	28	Sunnyside.	65	82	Sunnyside.	50	Cambridge.
1894	69.4	65.9	68.8	71.9	71.5	70.4	73.8	61.2	77.7	60.6	17.1	99	Charlotte Hall.	29	Sunnyside.	70	82	Oakland.	53	Solomon's.
1895	70.6	67.8	70.4	72.5	72.2	71.6	75.6	63.5	81.4	60.2	21.2	101	College Park.	27	Deer Park.	74	86	Oakland.	50	Ellicott City. Solomon's.
1896	66.6	64.2	66.6	68.0	67.2	67.1	71.0	59.3	76.9	55.8	21.1	98	Taneytown.	29	Deer Park.	69	87	Deer Park.	48	Solomon's.
1897	66.8	63.8	66.9	68.9	68.3	67.9	72.5	57.6	78.9	55.0	23.9	100	Taneytown.	22	Deer Park.	78	87	Deer Park.	47	Solomon's.
1898	69.9	67.0	69.0	71.8	71.4	70.3	74.4	60.6	80.4	58.4	22.0	100	Laurel.	29	Deer Park. Sunnyside.	71	85	Frostburg.	52	Baltimore. Laurel. Solomon's.
Averages.	67.8	65.3	67.3	69.3	69.2	68.8	....	....	78.0	57.6	20.4	....	....	....	....	....	....	....	....	....
OCTOBER.																				
1892	54.3	53.0	50.4	56.8	55.6	55.0	61.9	48.4	65.3	45.6	19.7	88	Cambridge.	13	Sunnyside.	75	78	McDonogh. Cumberland.	40	Solomon's.
1893	54.9	51.0	55.1	56.2	57.6	56.2	61.9	48.4	65.3	45.6	19.7	88	Cambridge.	13	Sunnyside.	75	74	Oakland.	36	Solomon's. Cambridge.
1894	55.8	51.0	55.8	58.2	58.7	57.6	61.3	48.4	65.4	46.3	19.1	88	Solomon's.	24	Sunnyside.	64	73	Oakland.	40	Solomon's.
1895	50.2	46.1	51.1	52.3	52.9	51.9	56.4	41.2	62.5	38.3	24.2	82	Jewell.	4	Deer Park.	78	69	Deer Park.	37	Cambridge.
1896	52.6	49.1	52.5	54.9	54.2	53.8	58.2	44.6	61.7	43.1	18.6	85	Charlotte Hall.	16	Deer Park.	69	71	Woodstock. Chestertown.	44	Annapolis.
1897	56.7	54.5	56.6	59.3	57.1	57.8	61.1	49.6	66.6	47.0	19.6	91	Taneytown.	20	Sunnyside.	71	80	Deer Park. Smithsburg.	45	Annapolis.
1898	57.3	54.4	56.1	59.0	58.2	58.8	61.7	48.0	65.7	47.2	18.5	89	Chase.	17	Sunnyside.	72	73	Frostburg.	36	Solomon's.
Averages.	54.5	51.3	53.9	56.7	56.3	55.9	....	....	64.6	44.7	19.9	....	....	....	....	....	....	....	....	....

COMPARATIVE TEMPERATURE DATA FOR MARYLAND AND DELAWARE.

NOVEMBER.

YEAR.	TEMPERATURE AVERAGES.											TEMPERATURE EXTREMES.								
	Entire section.	W. Md.	N. C. Md.	S. Md.	E. Md.	Delaware.	Highest local.	Lowest local.	Maximum.	Minimum.	Daily range.	Highest.	Station.	Lowest.	Station.	Absolute range.	Lowest maximum.	Station.	Highest minimum.	Station.
1892	42.9	42.1	42.6	44.7	43.1	43.6	46.8	40.0	51.2	35.9	15.3	77	Edgemont.	15	Edgemont.	62	65	Cumberland.	24	Mardela Springs.
1893	42.6	38.3	41.4	45.3	46.1	44.8	48.2	34.1	50.4	34.5	15.9	73	Mardela Springs. Charlotte Hall.	0	Sunnyside.	73	60	Oakland. Mt. St. Mary's. Chestertown.	30	Cambridge.
1894	41.8	37.7	41.9	44.1	45.3	42.1	48.7	33.4	50.1	33.0	17.1	80	Denton.	2	Deer Park.	78	65	Deer Park.	26	Solomon's.
1895	45.8	42.0	45.8	46.7	48.8	47.9	52.8	37.8	54.8	33.2	21.6	81	Hancock.	0	Deer Park.	81	67	Annapolis.	30	Ellicott City.
1896	49.4	46.2	49.5	51.2	50.7	51.6	54.2	42.0	59.0	39.8	19.2	78	Westernport. Milford. Millsboro.	12	Sunnyside.	66	69	Deer Park. Van Bibber.	35	Annapolis.
1897	45.0	43.0	44.0	47.5	47.3	46.6	54.0	38.0	53.7	36.3	17.4	80	New Market.	8	Grantsville.	72	64	Chestertown.	29	Annapolis.
1898	42.9	40.7	42.0	44.9	44.6	44.2	50.6	35.9	51.3	34.2	17.1	78	Pocomoke City.	—6	Deer Park.	84	61	Fallston. Frostburg.	28	College Park.
Averages.	44.3	41.4	43.9	47.8	46.6	45.8	....	....	52.9	35.3	17.7	....	....	....	....	....	....	....	....	....

DECEMBER.

YEAR.	Entire section.	W. Md.	N. C. Md.	S. Md.	E. Md.	Delaware.	Highest local.	Lowest local.	Maximum.	Minimum.	Daily range.	Highest.	Station.	Lowest.	Station.	Absolute range.	Lowest maximum.	Station.	Highest minimum.	Station.
1892	32.3	32.2	36.6	34.0	32.1	31.9	36.0	29.4	39.3	26.3	13.0	68	McDonogh.	6	Roettcherville. Woodstock.	62	55	Easton.	16	Solomon's.
1893	36.6	33.0	35.6	39.5	38.3	39.4	41.4	29.4	41.4	29.4	12.0	68	Charlotte Hall. Millsboro. Upper Marlboro.	5	Charlotte Hall.	63	56	Sunnyside. Oakland.	22	Cambridge.
1894	36.0	32.3	35.4	38.1	39.1	36.8	41.9	29.8	44.4	27.8	16.6	72	Pocomoke City,	—10	Sunnyside. Deer Park.	82	50	Deer Park.	17	College Park.
1895	37.2	32.9	36.9	38.7	40.8	40.0	44.6	29.6	45.5	29.0	16.5	70	Pocomoke City.	—7	Deer Park.	77	61	Baltimore.	22	Pocomoke City.
1896	34.0	32.4	34.1	36.3	35.0	34.2	40.2	28.9	41.8	25.9	15.9	70	Charlotte Hall.	—2	Sunnyside.	72	57	Deer Park.	16	Annapolis. Solomon's.
1897	36.9	34.6	36.1	38.9	39.5	37.9	45.4	30.6	44.5	29.3	15.2	74	Pocomoke City.	—4	Deer Park.	78	59	Deer Park. Van Bibber.	18	Annapolis.
1898	34.2	31.1	33.4	36.2	36.8	36.6	44.6	26.5	41.2	25.8	15.4	70	Pocomoke City.	—20	Deer Park.	90	58	Deer Park and a number of other stations.	17	Milford. Solomon's.
Averages.	35.3	32.6	35.4	37.4	37.4	36.7	....	....	42.6	27.6	14.9	....	....	....	....	....	....	....	....	....

ANNUAL, JANUARY AND JULY TEMPERATURES ALONG THE 40TH PARALLEL N. LATITUDE.

	Lat.	Long.	Elev.	Year.	Jan.	July.
Baltimore, Md	38° 18′ N.	76° 37′ W.	123 ft.	55	34	77
Cincinnati, O	39° 06′ N.	84° 30′ W.	553 "	55	32	77
Denver, Col	39° 45′ N.	105° 00′ W.	5218 "	49	28	72
Salt Lake City, Utah	40° 46′ N.	111° 54′ W.	4282 "	51	28	76
Sacramento, Cal	38° 35′ N.	121° 20′ W.	35 "	60	46	73
Azores	38° 00′ N.	26° 35′ W.	115 "	72	57	63
Madrid, Spain	40° 24′ N.	3° 42′ E.	2149 "	56	40	77
Naples, Italy	40° 52′ N.	14° 15′ E.	489 "	61	48	76
Athens, Greece	37° 58′ N.	23° 44′ E.	337 "	63	46	81
Peking, China	39° 57′ N.	16° 28′ E.	123 "	53	23	79

JANUARY TEMPERATURES SAME AS AT BALTIMORE.

	Lat.	Long.	Elev.	Jan.	July.	Year.
Baltimore, Md	39° 18′ N.	76° 37′ W.	123 ft.	34	77	55
Cairo, Ill	37° 00′ N.	89° 70′ W.	317 "	35	79	58
Louisville, Ky	38° 15′ N.	85° 45′ W.	455 "	34	78	57
Prescott, Ariz	34° 33′ N.	112° 28′ W.	5383 "	34	74	53
Hanover, Germany	52° 22′ N.	9° 44′ E.	190 "	34	64	48
Bremen, "	53° 05′ N.	8° 48′ E.	16 "	33	63	48
Niigata, Japan	37° 55′ N.	139° 03′ E.	33 "	34	79	55
Sitka, Alaska	57° 03′ N.	135° 19′ W.	15 "	31	56	43

JULY TEMPERATURES SAME AS AT BALTIMORE.

	Lat.	Long.	Elev.	July.	Jan.	Year.
Baltimore, Md	38° 18′ N.	76° 37′ W.	123 ft.	77	34	55
Washington, D. C.	38° 54′ N.	77° 03′ W.	80 "	77	48	55
Cincinnati, O	39° 06′ N.	84° 30′ W.	553 "	77	32	55
Kansas City, Mo.	39° 05′ N.	94° 37′ W.	597 "	77	25	53
Lincoln, Neb	40° 48′ N.	96° 40′ W.	1181 "	77	23	50
Algeria, Africa	36° 48′ N.	30° 03′ E.	66 "	77	54	65
Madrid, Spain	40° 24′ N.	3° 42′ E.	2149 "	76	41	56
Venice, Italy	25° 26′ N.	12° 18′ E.	69 "	76	37	56
Rome, Italy	41° 54′ N.	12° 29′ E.	164 "	77	44	60
Jerusalem, Syria	31° 47′ N.	35° 13′ E.	2493 "	76	47	63
Tokio, Japan	35° 41′ N.	139° 46′ E.	66 "	77	36	56

ANNUAL TEMPERATURES SAME AS AT BALTIMORE.

	Lat.	Long.	Elev.	Year.	Jan.	July.
Baltimore, Md	39° 18′ N.	76° 37′ W.	123 ft.	55	34	77
Cincinnati, O	39° 06′ N.	84° 30′ W.	553 "	55	32	77
St. Louis, Mo	38° 38′ N.	90° 12′ W.	469 "	55	30	79
San Francisco, Cal	37° 48′ N.	122° 26′ W.	26 "	56	50	58
Wichita, Kan	37° 41′ N.	97° 20′ W.	1294 "	55	31	78
Madrid, Spain	40° 24′ N.	3° 42′ E.	2149 "	56	41	76
Venice, Italy	45° 26′ N.	12° 18′ E.	69 "	56	37	76
Bordeaux, France	44° 51′ N.	0° 34′ W.	39 "	55	42	69
Santiago, Chile	33° 27′ S.	70° 40′ W.	530 "	56	68	46
The Earth	....	....	....	59	55	63

Precipitation.

Perfectly dry air can be obtained by artificial methods, but in its natural and free state the vapor of water is always present. The capacity of the atmosphere for aqueous vapor is limited, and is decreased by cooling. When the point of complete saturation is reached, the excess of moisture is condensed into visible form, producing clouds, and if the process of condensation is rapid, the particles of water enlarge, and are brought to the surface of the earth by the force of gravity. The rate of condensation determines whether the fall is in the nature of mist, light showers or heavy rain, and the conditions of temperature, electrical tension, etc., determine the character—whether rain, sleet, snow or hail. These four forms are included under the general term of precipitation. Dew deposits are frequently heavy, and a dense fog may appreciably dampen exposed surfaces. The amounts are usually so small, however, that they may be disregarded when speaking of precipitation measurements.

A measure of the amount of precipitation that falls on the surface of the earth is obtained through the use of a rain gauge. In order to accurately measure small amounts, the upper part of the gauge, or receiver, has an area ten times greater than the inner tube, or collector. Therefore the amount collected in the tube will represent in depth, when measured by a rule graduated to tenths of an inch, ten times the actual fall that occurred over a given surface; or, when so measured, as is done in actual practice, the graduated tenths of an inch on the rule will equal only hundredth of an inch of the catch or true depth of the rainfall.

The *exposure* of the rain gauge is an important matter. It has been discovered that a gauge placed on the roof of a building will catch less rain than one located on the ground. Sheltering influences, such as trees or buildings, will affect the measurements, and, when a comparative study of rainfall is intended, any change in the location or elevation of the gauge will impair the value of the series of records obtained. An ideal exposure is in an open level field, remote from obstructions, with the top of the gauge only a few feet above the surface of the ground.

Rainfall observations have been general in Maryland only since the establishment of the State Weather Service. The longest voluntary records have been made in the northern-central counties. The most satisfactory of all are the U. S. Weather Bureau records for Baltimore and Washington, which have been continuous since 1871.

NORMAL ANNUAL PRECIPITATION AND ITS DISTRIBUTION.

The normal annual amount of precipitation for the entire state of Maryland, whether falling as rain, hail, sleet or snow, is about 43 inches. The local variations from this value are shown in Plate LIV.

The greatest normal annual amounts occur over the western part of the Alleghany Plateau, where conditions favor both *frequency* and *intensity* of rainfall and snowfall—*frequency*, because it is the section of Maryland lying nearest to the main storm tracks of the eastern United States; and *intensity*, because the greatest elevations of the state are found there, and these, obstructing the flow of moisture-bearing winds, force them up the sides of the mountain slopes, lower the temperature, and consequently the vapor capacity, of the air; the result being rapid condensation and heavier rainfall than would occur over a more level country. At Sunnyside, in Garrett county, the average annual precipitation for the past six years is 53.5 inches, or over ten inches greater than the normal annual fall for the state. This station has an elevation of 2500 feet above sea-level, and is situated on the western slope of the Backbone Mountain—a ridge running southwest and northeast, with elevations of 3000 feet.

Just east of the Alleghany Plateau the annual rainfall decreases rapidly over an area including eastern Allegany county and the greater part of Washington county, or, more strictly, the Greater Appalachian Valley. A second area of diminished precipitation is found over upper St. Mary's county and the southern part of Charles county, and a third over narrow portions of Maryland and southern Delaware, bordering on the Atlantic. These three have a normal annual rainfall of 31 to 35 inches, and are the driest regions of the two states.

The normal annual precipitation increases east of the Blue Ridge, over the Piedmont Plateau. Parr's Ridge divides the plateau into

two rainfall divisions; west of the ridge the annual amounts are about 40 inches, while east of the ridge there is a general increase to 45 inches.

A narrow area over which the normal annual fall is less than 40 inches lies just west of the Atlantic coast area already mentioned as one of the dry divisions, and a second limited area of this kind is found to embrace portions of Caroline, Talbot, Prince George's, Howard and Baltimore counties. With these exceptions, and that already noticed in portions of Charles and northern St. Mary's counties, the normal annual precipitation for the Coastal Plain is from 42 to 48 inches. The bands of greatest precipitation in this latter area include southern Anne Arundel county, and from southern St. Mary's county northeastward over portions of Dorchester and Wicomico counties.

NORMAL SEASONAL PRECIPITATION AND ITS DISTRIBUTION.

The normal annual precipitation is divided throughout the seasons as follows: spring and summer will have about 11.5 to 12 inches, and fall and winter 9.5 to 10 inches. This gives a slight excess for the growing season, which holds good for all parts of the state. During the growing season of spring and summer the total normal precipitation is about 24 inches for the regions bordering on the Bay and generally throughout the northern-central counties east of the Blue Ridge; the greatest amounts, 24 to 28 inches, fall over the Alleghany Plateau; the least, 20 to 21 inches, occur over the Greater Appalachian Valley and much of the district bordering on the middle and lower Potomac.

The local distribution for each season is shown on Plates L-LIII.

NORMAL MONTHLY PRECIPITATION AND ITS DISTRIBUTION.

Maryland belongs to the Middle Atlantic and New England type of rainfall distribution, of which Mr. A. J. Henry[1] says:

"Distribution of rain in this region is more uniform than in any other part of the country; the range between months of greatest and least rainfall is very small and of little practical importance. The precipitation of

[1] Bulletin D. Rainfall of the United States. U. S. Department of Agriculture, Weather Bureau, Washington, 1897.

DIVISIONS.	STATIONS.	No. Years Record.	Jan.	Feb.	Mar.	[illegible]
Alleghany Plateau.	Sunnyside	5–6	4.3	5.0	5.0	[illegible]
The Greater Appalachian Valley.	Cumberland	26–28	2.3	2.7	3.0	[illegible]
	Green Spring Furnace	5–6	2.4	2.9	2.6	[illegible]
	Mean		2.4	2.8	2.8	[illegible]
Central Potomac District.	Great Falls	8–9	2.9	2.9	3.0	[illegible]
	Washington	25	3.5	3.4	4.2	[illegible]
	Mean		3.2	3.2	3.6	[illegible]
North Central District.	Frederick	20–24	3.2	3.0	3.0	[illegible]
	Emmitsburg (Mt. St. Mary's)	20–29	3.1	3.2	4.1	[illegible]
	New Market	9–13	2.6	3.3	3.7	[illegible]
	Sandy Spring	7–8	3.5	3.4	4.1	[illegible]
	Woodstock	20–28	3.5	3.4	4.0	[illegible]
	McDonogh	17–18	3.0	3.1	3.7	[illegible]
	Baltimore	47–51	3.0	3.5	4.0	[illegible]
	Fallston	26–29	3 7	4.1	4.3	[illegible]
	Woodlawn	11	3.1	3.6	4.2	[illegible]
	Mean		3.2	3.4	3.9	[illegible]
Anne Arundel County.	Annapolis	18–22	3.2	3.6	4.3	[illegible]
	Jewell	8–10	2.8	3.6	4.8	[illegible]
	Mean		3.0	3.6	4.6	[illegible]
Southern District. Western Shore.	Charlotte Hall	4–6	2.8	3.2	3.1	[illegible]
	Solomon's	7	2.6	4.0	3.2	[illegible]
	Cherryfields	5–6	1.9	3.5	3.3	[illegible]
	St. Inigoes	7–8	2.5	4.1	4.9	[illegible]
	Mean		2.4	3.7	3.6	[illegible]
Eastern Shore.	Chestertown	6–13	2.9	2.6	3.3	[illegible]
	Easton	7–8	2.7	3.7	3.3	[illegible]
	Mardela Springs	10–11	2.9	4.0	4.4	[illegible]
	Mean		2.8	3.4	3 7	[illegible]
Delaware and Atlantic Coast.	Dover, Del.	15–18	3 2	3.5	4.5	[illegible]
	Milford, Del.	14–16	2.9	4.5	3.7	[illegible]
	Millsboro, Del.	6	2.9	4.3	3.1	[illegible]
	Mean		3.0	4.1	3.8	[illegible]
Entire Section.	Mean		3.0	3.6	3.9	[illegible]

* Record

Jun.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.	Spring.	Summer.	Autumn.	Winter.
4.7	6.2	3.6	3.1	3.4	4.3	4.0	53.3	14.8	14.5	10.7	13.3
3.6	3.4	3.1	2.7	2.5	2.4	2.2	33.7	8.8	10.0	7.5	7.2
2.8	3.8	4.3	2.8	2.9	2.9	2.3	35.4	8.4	10.9	8.6	7.5
3.2	3.6	3.7	2.8	2.7	2.6	2.8	34.6	8.6	10.4	8.0	7.4
2.5	3.6	2.6	3.1	2.3	2.8	2.8	35.2	9.7	8.7	8.1	8.6
4.0	4.6	4.0	3.7	3.1	2.8	3.0	43.5	11.4	12.6	9.6	9.9
3.3	4.1	3.3	3.4	2.7	2.8	2.9	39.4	10.6	10.6	8.8	9.2
4.2	3.7	2.8	3.4	2.5	2.9	2 9	38.9	10.4	10.6	8.9	9.0
3.9	3.5	3.5	3.6	3.8	3.9	3.0	43.2	11.8	10.9	11.3	9.3
3.4	4.1	4.3	3.8	2.8	4.5	2.5	42.2	11.0	12.0	11.1	8.4
5.0	5.1	4.9	3.3	3.7	3.1	3.4	45.2	10.0	15.0	10.1	10.3
3.5	3.6	4.1	3.6	3.4	3.3	2.7	42.3	11.2	11.3	10.3	9.6
3.9	4.0	3.2	3.5	2.7	3.0	2.5	38.2	9.3	11.1	9.2	8.6
3.7	4.7	4.1	3.6	3.1	3.3	3.2	43.3	11.3	12.4	10.0	9.6
4.0	4.5	4.9	4.3	3.6	3.8	3.4	48.3	12.0	13.4	11.7	11.2
3.9	4.3	5.7	4.0	4.0	4.0	3.0	47.8	12.1	14.0	12.0	9.7
4.0	4.2	4.2	3.7	3.3	3.5	3.0	43.3	11.0	12.3	10.5	9.5
4.0	4.8	4.6	3.7	3.8	4.3	3.4	48.2	12.9	13.3	11.9	10.2
3.7	7.0	3.4	3.7	3.7	3.3	2.9	47.9	13.9	14.1	10.7	9.3
3.8	5.9	4.0	3.7	3.8	3.8	3.2	48.0	13.4	13.7	11.3	9.8
*2.5	4.0	2.5	1.3	3.7	2.1	2.0	*34.4	*10.5	9.0	*7.1	8.0
3.3	4.2	3.2	2.0	3.2	3.0	2.6	38.6	10.6	10.7	8.1	9.2
2.7	6.0	3.4	2.2	3.3	3.2	2.5	39.9	10.6	12.1	9.3	7.9
2.1	3.7	6.5	4.8	3.7	3.4	3.4	47.6	13.4	12.3	11.9	9.9
2.7	4.5	3.9	2.6	3.6	2.9	2.6	40.1	11.3	11.0	9.1	8.8
3.9	3.5	5.4	3.4	3.0	3.3	2.7	42.6	12.0	12.7	9.7	8.2
2.7	4.2	3.3	2.2	3.0	2.9	2.6	37.8	10.6	10.2	8.1	9.0
2.1	6.6	3.6	3.4	4.6	3.3	2.3	45.7	12.9	12.3	11.4	9.2
2.9	4.8	4.1	3.0	3.5	3.2	2.5	42.0	11.8	11.7	9.7	8.8
3.2	4.8	3.6	3.9	3.3	3.5	3.1	42.9	11.1	11.5	10.7	9.7
3.1	3.4	3.3	4.6	3.5	3.5	3.0	42.9	11.1	9.8	11.6	10.3
3.1	5.3	3.4	3.7	4.9	3.2	3.0	45.7	12.0	11.9	11.8	10.2
3.1	4.5	3.4	4.1	3.9	3.4	3.0	43.8	11.4	11.0	11.4	10.1
3.5	4.8	3.8	3.3	3.4	3.3	3.0	43.1	11.6	11.9	9.9	9.6

broken.

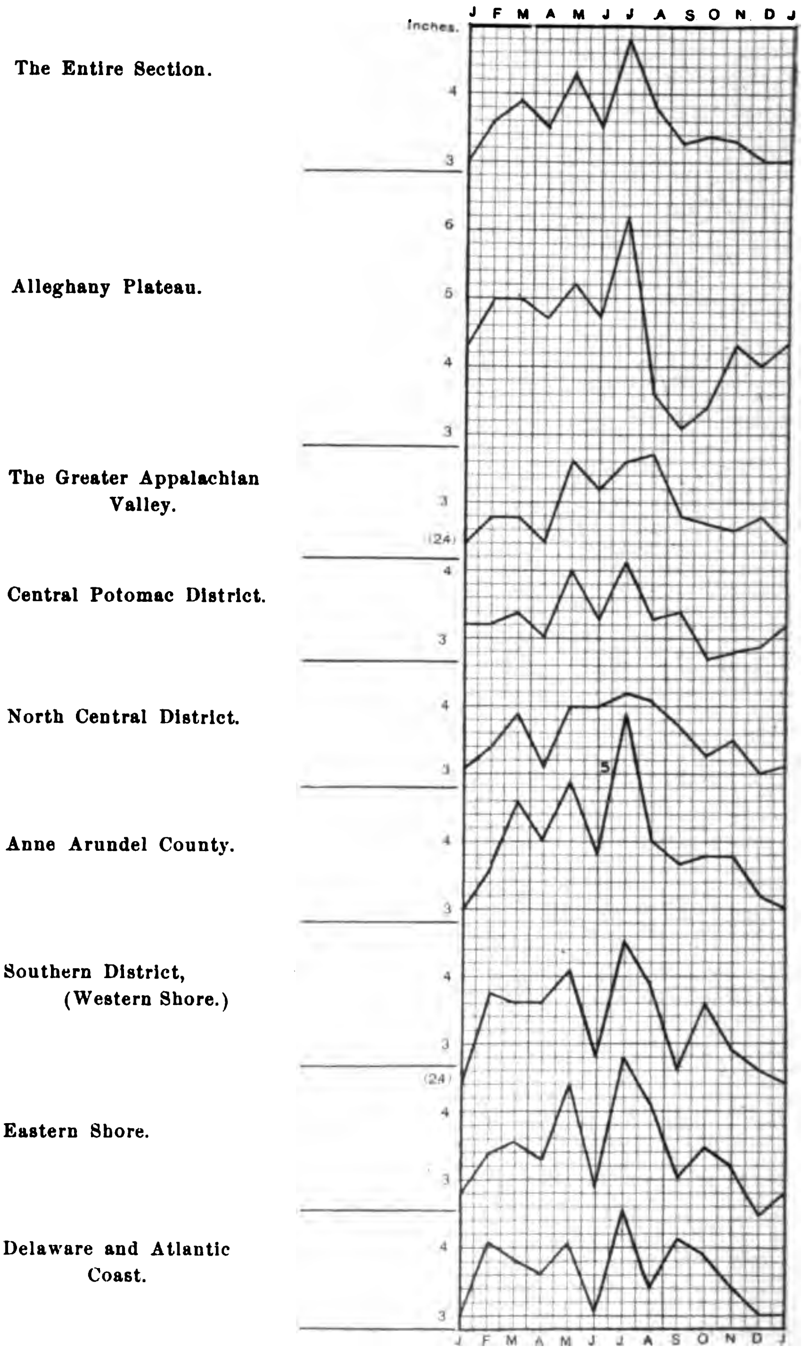

FIG. 59.—Fluctuations in normal rainfall.

this region is uniformly distributed throughout the year and there is sufficient on an average for the needs of commerce and agriculture. Its geographical position is favorable for moderate precipitation during all seasons, being almost in the direct course of atmospheric disturbances, either advancing from the southwest or by way of the Lake region."

This statement is borne out by the tables and charts of normal precipitation published with this article, Plates XXXVIII-XLIX. There is no very decided rainy season. May and July are the two months having the greatest average amounts of rainfall, but the variations are such that quite a number of years can be found in which the records will show greater rainfall in other months than in either May or July.

In examining the local distribution of rainfall as shown by the tables and charts it became apparent that the entire state could be grouped into districts, each having a common type of rainfall conditions for the several months and seasons. These groupings determined the arrangement of the data given in the table of normal precipitation by districts, and afterwards formed the basis of Figure 59, showing the fluctuations of normal rainfall in the several districts. It will be understood that the irregular lines in the figure have no value other than as connecting points on the vertical lines which represent the average monthly rainfall.

The features of rainfall distribution common to all types are: the decrease in April; the increase in February and May, and the very marked increase in July.

The very decided decrease in June is noticeable in every section except over the northern-central counties, where the normal rainfall conditions are almost uniform from May to the first of September. A decrease in rainfall is generally found in the fall months except over the Eastern Shore and the southern counties of the Western Shore, where there is an increase in the month of October. Comparatively smaller amounts of precipitation occur in the months of December and January in all sections.

Over the Alleghany Plateau the decrease in rainfall from July to September is very marked. This period of decreased rainfall is coincident with the period of least storm frequency.

VARIABILITY OF PRECIPITATION.

NORMAL MONTHLY AND ANNUAL PRECIPITATION, WITH THE GREATEST AND LEAST AMOUNTS RECORDED IN ANY SINGLE MONTH OR YEAR, FOR THE STATIONS HAVING THE LONGEST AND MOST RELIABLE RECORDS.

STATION.	Jan.	Feb.	Mar.	Apr.	May	Jun.	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
Annapolis	3.2	3.6	4.3	3 9	4.7	4.0	4.8	4.6	3.7	3.8	4.3	3.4	48.2
	5.8	7.5	10.2	7.2	8.1	8.9	8.8	14.6	10.6	8.4	5.5	6.4	64.0
	1.3	0.5	0.7	1 1	2.2	0.9	1.2	0.9	1.4	0.1	1.8	0.3	38.6
Bachman's Valley	2.6	3.8	4.2	4.0	6.9	2.9	4.0	3.8	3.6	3.4	4.3	3.3	46.9
	4.2	6.2	6.2	6 4	12.3	5.1	5.1	5.6	7.9	6.1	8.4	6.0	57.5
	1.2	0.7	1.9	1.6	2.7	0.9	2.8	1.8	1.8	2.1	1.8	1.0	37.3
Baltimore	3.0	3.5	4.0	3.3	4.0	3.7	4.7	4.1	3.6	3.1	3.3	3.2	43.3
	6.4	7.1	9.1	8.7	8.0	9.2	11.0	11.0	10.7	7.8	8.3	6.3	62.4
	0.7	0.7	1.2	0 5	1.2	0.7	1.4	0.3	0.1	0.2	0.6	0.4	28.8
Fort McHenry	2 5	2 8	3.5	3.0	3.5	3.4	3.6	4.0	3.4	2.9	3.0	3.3	38.9
	7.1	5.9	6.6	9.1	12.0	9.2	10.2	9.7	10.5	7.4	7.9	8.8	66.4
	0.3	0.1	1.3	0.4	0.2	0.6	0.3	0.3	T	T	0.1	0.3	22.4
Cumberland	2.3	2.7	3.0	2.3	3.5	3.6	3.4	3.1	2.7	2 5	2.4	2.2	33 7
	4.6	4.9	7.5	6.5	7.1	7.7	5.6	8.1	8.5	6.9	5.3	4.5	46.3
	0 3	0.6	0.5	0.6	0 3	0 9	1.0	0.3	0.2	0.3	0.4	0 7	22.5
Darlington	3.1	3.2	2 9	3.3	6.6	3 4	4.3	3.6	3.6	3.2	3.9	2.7	41.8
	5.6	5.1	4 9	6.7	8.1	5 2	6 8	10.4	7.0	5.9	5.6	4.0	51.0
	1.3	1.6	1.3	1.4	2.5	1.3	2.0	1.3	1.9	0.4	1.4	0.3	36.2
Easton	2.7	3 7	3.3	3.1	4.2	2.7	4.2	3.3	2.2	3.0	2.9	2.6	37.8
	4.6	6.0	5.0	4.6	6.5	4.1	8.3	5.0	4.0	5.3	4.1	4.0	43.7
	1.2	1.6	0.8	1.7	3.1	1.3	2.3	1.1	0.7	0.8	1.2	1.0	30.9
Fallston	3.7	4.1	4.3	3.4	4.3	4.0	4.5	4.9	4.3	3.6	3 8	3.4	48.3
	6 6	7.0	8.8	8.5	10.4	10.2	12.4	11.6	13.0	7.6	10.3	7.0	68.6
	1.2	1.5	1.4	1 3	0.7	1.0	1.4	1.0	0.2	0.2	0.5	0.4	35.2
Frederick	3.2	3.0	3.0	3.5	3.9	4.2	3.7	2.8	3.4	2.5	2 9	2.9	38.9
	5.5	6.2	6.3	6.2	9.5	10.8	7.6	7.4	11 4	5.8	6.3	6.3	51 8
	0 6	0.8	1.0	1.1	0.4	0.7	1.6	0.3	1.2	0.2	0.8	0.6	30.6
Green Spring Furnace	2.4	2.9	2.6	2.1	3.7	2.8	3.8	4.3	2.8	2.9	2.9	2.3	35.4
	3.4	4.8	4.0	2.6	5.2	4.4	4.8	6.9	5.0	6.0	4.8	3.9	40.9
	1.5	1.2	1.6	1.3	1.6	0.8	2.2	0.9	1.2	1.0	1.5	0.6	31.4
Jewell	2.8	3.6	4.8	4.0	5.1	3.7	7.0	3.4	3.7	3.7	3.3	2.9	47.9
	5.1	5 6	8 4	12.2	7.3	5.7	19.9	6.9	9.2	6 2	6.6	5.6	65.7
	1.3	1.2	2.8	1.2	4.2	1.0	2.5	0.9	0.9	0.4	0.8	T	36.2
Mardela Springs	2.9	4.0	4.4	4.3	4.2	2.1	6.6	3.6	3.4	4.6	3 3	2.3	45.7
	4.8	6.6	7.5	6.7	7.2	5 4	12 5	8.9	6.9	8.3	6.4	4.0	63.2
	1.0	2.0	1.4	1.5	2.9	0.7	1.9	1.3	1.2	0.1	0.9	0.2	36.8
McDonogh	3.0	3 1	3.7	2.2	3.4	3.9	4.0	3.2	3.5	2.7	3.0	2.5	38.2
	5.8	6 0	6.6	4.8	7 6	7.5	9.5	7.1	7.9	6.4	8.6	4.3	59.9
	0.8	1.1	1.2	0.8	0.7	1.8	1.9	0.3	0.2	0.3	0.5	0.4	31.6
Mt. St. Mary's	3.1	3.2	4 1	3.1	4.7	3.9	3.5	3.5	3.6	3 8	3.9	3.0	43.2
	5.6	5.3	6.7	5.6	10.2	9.6	8.0	8.9	8.9	8.8	11.0	7.5	51 3
	0.8	1.1	0.7	0.9	1.6	0.1	1.3	0.9	0.8	0.8	1.0	0.6	33.8
St. Inigoes	2.5	4.1	4.9	4.2	4.3	2 1	3.7	6.5	4.8	3.7	3.4	3.4	47.6
	4.4	8.8	12.8	13.0	9.8	3.7	10.6	15.2	7.8	11.0	6.6	6.7	88 5
	0.5	1.0	1 9	1.4	1.3	0.5	1.5	1.0	0.8	0.2	1.2	1.2	29.7
Solomon's	2.6	4.0	3.2	3.5	3.9	3.3	4.2	3.2	2.0	3.2	3.0	2.6	38.6
	5.1	6.4	4.7	5.5	4.6	5.7	7.4	7.9	3.2	5.4	4.7	3.3	43.5
	1.5	1.3	1.2	1.2	2.4	0.9	2.3	1.0	0.5	0.7	1.9	0.9	32.1
Washington	3.5	3.4	4.2	3.3	3.9	4.0	4.6	4 0	3.7	3.1	2.8	3.0	43.5
	7.1	6.8	8.8	9.1	10.7	8.6	10.6	12.9	10.8	8.7	7.2	6.1	61.3
	0.2	0.9	1.0	1.1	1.0	1.2	0.8	0.8	0.1	0.3	0.8	0.2	30.8
Woodlawn	3.1	3.6	4.2	3.7	4.3	3.9	4.3	5.7	4.0	4.0	4.0	3.0	47.8
	5.0	5.9	7.3	8.4	7.6	9.4	8.7	11.8	9 0	7.7	8.4	6.0	54.4
	1.0	0.9	1.6	1.8	1.1	0.4	1.4	1.1	1.1	0.4	2.2	1.2	35.5
Woodstock	5.3	3.4	4.0	3.1	4.1	3.5	3.6	4.1	3.6	3.4	3.3	2.7	42.3
	11.2	6.7	7.6	6.4	10.3	8.9	6.0	10.3	8.2	10.2	9.8	4.9	57.8
	0 8	1.0	0.8	1.2	1.5	1.1	1.6	0.9	0.2	0.2	0.4	0.6	26.3

NOTE.—For each station is given (1) the average, (2) the greatest amount, and (3) the least amount recorded for the entire period of observation.

MONTHLY AND ANNUAL EXTREMES OF PRECIPITATION.

That there is a great variability in the amounts of rainfall for the various months during the periods covered by the records for the several stations, is shown by a reference to the Tables on pp. 518-519, which give the monthly and annual extremes of rainfall. This variability is especially marked in the spring and summer season, although at some stations very decided ranges are found in September and October. A few examples of extreme ranges in August are: The range at Annapolis from over 14 inches to less than 1 inch; at Baltimore, of 11 inches to 0.3 of an inch; at Fallston from 11.5 inches to 1 inch;

GREATEST AND LEAST TOTAL MONTHLY AND ANNUAL RAINFALLS OCCURRING ANYWHERE IN STATE SINCE 1818.

January	11.2	Woodstock	1883
"	0.2	Washington	1872
February	8.8	St. Inigoes	1872
"	0.1	Fort McHenry	1864
March	12.8	St. Inigoes	1872
"	0.5	Cumberland	1872
April	13.0	St. Inigoes	1874
"	0.4	Fort McHenry	1847
May	12.3	Bachman's Valley	1898
"	0.2	Fort McHenry	1866
June	10.8	Frederick	1870
"	0.1	Mt. St. Mary's	1888
July	19.9	Jewell	1897
"	0.3	Fort McHenry	1869
August	15.9	Mount Airy	1873
"	0.3	Baltimore	1821
September	13.0	Fallston	1876
"	Trace	Fort McHenry	1884
October	11.0	St. Inigoes	1872
"	0.0	Taneytown	1892
"	0.0	Mount Airy	1874
November	11.0	Mt. St. Mary's	1881
"	0.1	Fort McHenry	1882
December	7.5	Mt. St. Mary's	1867
"	Trace	Jewell	1889
Annual	88.5	St. Inigoes	1872
"	22.5	Cumberland	1879
"	21.0	Cumberland	*1872
"	20.0	Cumberland	1870
"	22.4	Fort McHenry	1870

*February missing.

at St. Inigoes, 15.2 to 1 inch; at Washington, nearly 13 inches to 0.8 of an inch. The minimum rainfall record for a month has been as low as an inappreciable amount in September and an entire absence in October. The greatest rainfall ever recorded in any month was 19.9 inches at Jewell, in July, 1897. At the same station in July, 1893, the total fall was only 2.5 inches.

It has already been seen in discussing the normal annual distribution of precipitation that the normal range is from 32 inches in the driest to 52 inches in the wettest portions, while over the greater

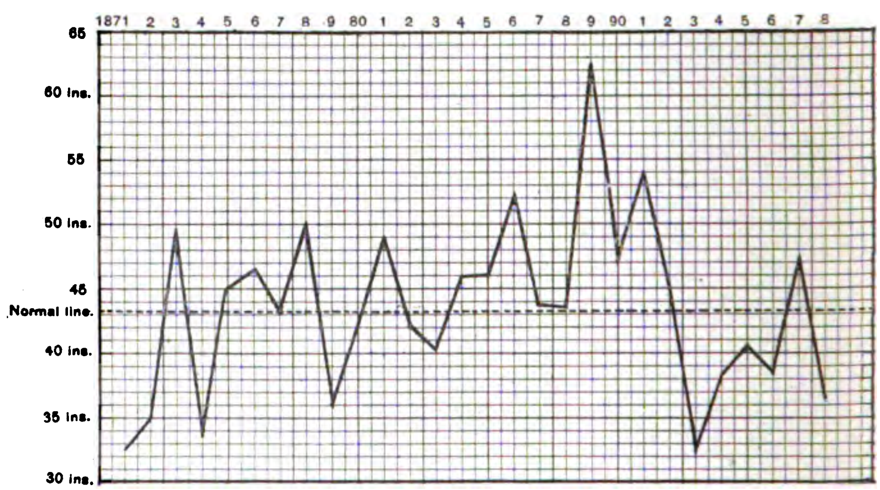

FIG. 60.—Fluctuations in annual precipitation at Baltimore, 1871–1898.

portion of the agricultural area of the state the normal range is from 35 to 45 inches. The extreme ranges of annual rainfall are of course much greater than this. They are given in the foregoing tables, which compare for stations with records of eight years or more the normal rainfall for each month and for the year, and the greatest and least amounts occurring during the period of observation. The Table on p. 519 furnishes the greatest and least total monthly and annual precipitation that has occurred anywhere within the state since 1818, with the exception of about ten years for which there is no obtainable record. The extremes of annual rainfall, as there shown, are a great-

est of 88.5 inches at St. Inigoes, in St. Mary's county, in 1872; and a least of 20 inches at Cumberland in 1870.

PRECIPITATION RECORDS FOR BALTIMORE.

The normal precipitation values computed for Baltimore agree very closely with the established normals for Maryland, and are representative of the conditions found over the greater part of its area. A short summary, then, of the Baltimore records will apply in a general way to the entire state, excluding necessarily the limited districts of greatest and least rainfall, already noted.

Reliable continuous rainfall observations at Baltimore date from the establishment of the U. S. Weather Bureau in 1871. The earliest known records were kept from 1818 to 1824. There is an absence of data from 1825 to 1836, but since then an almost unbroken record has been made. The earlier records have been obtained from various sources, and are not as a whole very trustworthy, but for purposes of general examination and discussion the entire series of available observations will be given a brief review.

Considering all records, July is the wettest and January the driest month. The normal amounts for the two are 4.66 inches and 2.99 inches respectively; or a normal range of only 1.67 inches between the months of greatest and least precipitation. The actual absolute range for the several months during the period of observation is very large. The rainfall for July has been as great as 11.03 inches, and as small as 0.30 inch, and the precipitation in January has been found to range from 6.42 inches to 0.70 inch. The average annual precipitation for Baltimore for the entire period is 43.44 inches; the greatest annual fall occurred in 1889, and measured 62.35 inches—an amount not usually found in the United States except along the south Atlantic, Gulf, and north Pacific coasts; the least annual fall recorded was 22.43 inches in 1870.

PERMANENT OR PERIODIC INCREASE OR DECREASE IN PRECIPITATION.

For a really satisfactory comparative study of precipitation at Baltimore only the known reliable records of 1871-1899 can be used. These have been examined with a view to finding whether or not they show any permanent change in the amounts of precipitation since

the beginning of observations, or whether the fluctuations known to exist take place at regular periods. The fluctuations of annual precipitation for all years since 1871 are shown on Figure 60. From this figure it will be seen that there have been eight distinct periods during which the rainfall was above, and four when it ranged below, the normal. The only prolonged periods with annual amounts continuously above normal were 1875-1879, and 1884-1892, while but one period, 1893-1896, is found where the annual amounts were continuously below the normal for four successive years. A closer inspection of the figure also discloses the fact that there was a gradual rise in the precipitation curve from 1871 to 1889, inclusive, despite occasional lapses, while from 1890 to 1894, inclusive, there was a rapid descent in the curve. Since that time the curve has been rising, corresponding very closely to the rise that began in 1871 and continued with minor interruptions for nineteen years. Nothing is to be inferred from this, unless it is that a recurring period, which has been shown as barely possible, should be found to exist in fact. In that case it might be expected that a period of gradual, though irregular, increase in rainfall would ensue, and last for about fifteen years. There is no justification, through known laws or facts, for a belief that this will take place.

PERIODS OF DROUGHT.

Facts regarding drought in Maryland are not obtainable except for the past seven years. During that time there have been several periods of extended dry weather. Some of these have been sufficiently prolonged to cause a shortage in yield, but there has never been a complete loss of any crop.

The following table shows the number of dry and wet months, and years, at Baltimore since 1870.

	Jan.	Feb.	Mar.	Apr.	May.	Jun.	July.	Aug.	Sep.	Oct.	Nov.	Dec.	Years.
Wet......	3	6	5	3	6	4	9	6	4	4	2	4	4
Dry......	1	1	6	5	6	3	4	8	6	4	2	3	3

In obtaining the above figures, a year has been considered wet when the precipitation was 50 inches or more; dry when less than 35 inches. Abnormally wet and dry months were determined as follows: During the growing season from March to September inclusive—wet

when six inches or more occurred in a single month; dry when two inches or less fell. During the other months—wet with five inches or more; dry with one inch or less.

The normal rainfall for Baltimore for the critical period of the growing season—May to August inclusive—is 16.5 inches, as obtained by averaging the records for the entire period from 1871 to 1898. If this be divided into three periods it is found that the first, 1871-1878, gives an average amount of 15.1 inches; the second, 1879-1888, 17.6 inches; and the third, 1889-1898, 16.4 inches; or a range of about 2.5 inches for the three periods. A further examination of the Baltimore records shows that there has been no drought of three months' duration from April to August. By including September, two drought periods of three successive months are obtained; these occurred in 1870 and 1893.

Less protracted droughts at Baltimore during the growing season, were as follows:

Droughts extending over two consecutive months: 1874, May and June; 1884, August and September; 1894, July and August; 1896, April and May. Droughts of one month or longer, but not of two months: 1871, April; 1872, May and July; 1873, June; 1875, June; 1876, August; 1877, August; 1878, September; 1880, May and September; 1881, April and July; 1883, May; 1885, April and September; 1886, September; 1889, August; 1892, August; 1896, August; 1898, April and June.

The following statement shows the months of the growing season that have had a total rainfall of 2 inches or less, at the stations named; the period of time covered by the records is given for each station:

Annapolis (1857-76; 1894-98).—May, 1875 and 1897; June, 1858, 1864, 1897 and 1898; July, 1858 and 1859; August, 1869, 1870 and 1871.

Bachman's Valley (1894-98).—August, 1896; June, 1898.

Cherryfields (1894-98).—June, 1894; August, 1896.

Charlotte Hall (1893-98).—May, 1896; June, 1893, 1894 and 1898; August, 1895 and 1896.

Chestertown (1855-64; 1894-98).—June, 1863 and 1864; July, 1858, 1864; August, 1858 and 1864.

Cumberland (1871-98).—May, 1874, 1875, 1876, 1877, 1879, 1881 and 1895; June, 1874, 1879, 1885, 1893, 1894, 1897 and 1898; July, 1885, 1890, 1892, 1893, 1898; August, 1876, 1877, 1878, 1880, 1881, 1883, 1884, 1887, 1889, 1892, 1894, 1895 and 1896.

Fallston (1891-98).—May, 1874, 1875, 1880, 1883; June, 1873, 1874, 1898; July, 1872, 1881 and 1894; August, 1876, 1881 and 1896.

Dover, Del. (1870-80; 1891-98).—May, 1872, 1875, 1877, 1879, 1892, 1893 and 1894; June, 1873; July, 1875, 1895; August, 1871, 1876, 1877, 1895 and 1896.

Frederick (1852-70; 1889-98).—May, 1862, 1866, 1894, 1896; June, 1854, 1890, 1893, 1898; July, 1854, 1859, 1893 and 1898; August, 1854, 1859, 1862, 1871, 1889, 1892, 1893, 1894, 1895 and 1896.

Mardela Springs (1888-98).—June, 1890, 1891, 1892, 1893, 1894, 1895 and 1896; July, 1890 and 1895; August, 1889.

Washington (1870-1898).—May, 1872, 1875, 1879, 1881; June, 1873, 1893, 1894 and 1898; July, 1872, 1881 and 1893; August, 1871, 1874, 1881, 1884, 1892 and 1895.

A study of rainfall figures alone will not determine the extent to which drought conditions prevail. It is necessary to know whether the total amounts fell in light refreshing showers, well distributed throughout the month, or, as sometimes occurs, in one beating rain; the nature of the soil should also be considered, whether it parts readily with the moisture received or retains it for a longer time, gradually apportioning it to plant life as required for support and development. In a general way, however, the statements will indicate the extent to which brief or protracted periods of drought have prevailed in recent years.

PRECIPITATION FREQUENCY.

A study of the frequency of appreciable rainfall over any considerable portion of Maryland, for the period covered by the State Weather Service, shows that the average number of days during a year is in this state 168. The departure from this average during the seven years is very small. The greatest number of days of rain was 171 in 1898, and the least 163 in 1895. The average number of times per month on which rain falls over this state is 14, the greatest average occurring in any month being 18 in May, and the least average, 9, in October. The average number of days on which heavy rain occurs—or rain in excess of 0.75 of an inch—is about 45 in a year or 4 per month. In the six-year period of study the greatest number was 59 in 1897; and the least, 36 in 1895 and 1896. July has the greatest number of heavy rainfalls, which average about 7 for the month. The lowest number, 3, applies to nearly all of the other months except November and August, which have about 4. The greatest number of days with heavy rainfalls occurring over an extended area in any month was 13. These occurred in July, 1897, and in August, 1898.

The greatest number of consecutive days with appreciable rainfall

over a large part of the state was 17, from May 16 to June 1, 1894. Seven of these days had heavy rainfall.

The average and extremes of frequency of rainfall for the various months for the whole state as shown by the records for the past seven years are about as follows:

AVERAGE AND EXTREMES OF FREQUENCY OF RAINFALL OVER THE STATE.

	Average.	Maximum.	Minimum.
January	15	24	7
February	12	18	7
March	15	19	8
April	14	20	11
May	18	22	13
June	14	22	7
July	16	24	10
August	13	18	8
September	11	17	5
October	9	15	3
November	14	18	11
December	11	15	6

The figures in the above table indicate the average number of days with appreciable rainfall occurring over *any considerable area* of the state. In the table that follows there is given the average number of days with appreciable rainfall for a single station in each of the climatic divisions of the state during the past seven years, and the average and greatest and least number of days with appreciable rainfall at Baltimore for the past twenty-eight years:

NUMBER OF DAYS WITH APPRECIABLE PRECIPITATION.

	Jan.	Feb.	Mar.	Apr.	May.	Jun.	July.	Aug.	Sep.	Oct.	Nov.	Dec.
Western section	9.3	8.9	9.2	10.4	12.1	8.8	9.9	6.1	5.6	6.7	7.4	8.1
N. Central section	8.4	8.5	9.8	9.4	11.8	8.8	9.2	6.5	4.6	6.4	9.2	7.1
Southern section	8.2	8.3	9.2	8.6	10.4	7.3	9.0	6.6	5.5	6.2	8.5	6.2
Eastern section	9.1	8.8	10.4	9.1	11.9	7.1	9.5	7.5	5.6	6.9	9.1	7.9
Entire state	8.8	8.6	9.7	9.5	12.9	9.9	9.6	6.9	5.7	5.1	9.0	7.5
Baltimore.												
Average number.	12	11	13	11	12	11	12	11	9	10	11	11
Greatest number.	19	19	19	15	21	16	18	21	15	16	16	17
Least number.	5	5	8	6	5	6	7	6	2	2	6	5

EXCESSIVE RAINFALL.

Thus far, in the consideration of rainfall, attention has been paid principally to actual or accumulated amounts in inches for a given period, without particular reference to whether the total was composed of light, heavy or excessive individual amounts. Generally all kinds combine to form the total given. An examination of all available records for Maryland would seem to indicate that, on an average, the rainfall for any year will include about eight occurrences of excessive precipitation. This estimate of average annual frequency of excessive rainfalls is probably too small, since the earlier records were few in number. From tabulated data the average frequency from 1868 to 1878 was 5 excessive rainfalls; from 1879 to 1888 the average was 8, and from 1889 to 1898 the average was 12; so that in all probability there is likely to occur about ten dates of excessive rainfall each year.

The exact definition of an excessive rainfall, as here used, is one that gives one inch in an hour, or 2.5 inches in 24 hours. A month is considered as having excessive rainfall when it furnishes a total of 10 inches or more.

The exact figures regarding excessive rainfalls are of such especial value to a number of interests and professions that all available data have been collected in the accompanying tables. A study of these tables brings out the fact that days with excessive rainfall are most frequent in July and August, and least frequent in January and February.

TABLE SHOWING EXCESSIVE PRECIPITATION.

JANUARY.

Station.	Year.	Monthly rainfall, 10 inches or more.	Rainfall, 2.50 inches or more in 24 hours.		Rainfall of one inch or more in one hour.		
			Amt.	Date.	Amt.	Time.	Date.
Woodstock	1886		3.01	3–4			
Fallston			2.60	4			
Fort McHenry			2.70	4			
District of Columbia			3.07	4–5			
Green Spring Furnace	1896		2.50	23–24			
Sharpsburg			2.50	"			

FEBRUARY.

Station.	Year.	Monthly rainfall, 10 inches or more.	Amt.	Date.	Amt.	Time.	Date.
Baltimore	1886		2.60	11			
Jewell	1890		2.50	7–8			
Milford, Del	1895	11.05					
Dover, Del	1896		3.25	5–6			
Millsboro, Del			3.25	5–6			
Newark, Del			2.65	5–6			
Seaford, Del			3.70	5–6			
Wilmington, Del			2.67	6			
Bachman's Valley			3.42	5–6			
Baltimore			3.48	5–6			
Cambridge			4.00	5–6			
Easton			3.06	5–6			
Fallston			2.96	5–6			
Frederick			2.50	6			
Jewell			2.52	5–6			
Mardela Springs			3.00	5–6			
Mt. St. Mary's			2.96	6			
Pocomoke City			3.21	5–6			
Princess Anne			3.80	5–6			
Solomon's			3.75	5–6			
Upper Marlboro			3.45	6			
Westminster			3.80	6			
Bachman's Valley	1897		2.60	23			
Cumberland			2.70	22–23			

MARCH.

Station.	Year.	Monthly rainfall, 10 inches or more.	Amt.	Date.	Amt.	Time.	Date.
Woodstock	1881		3.25	8–9			
Sandy Spring			2.55	"			
Baltimore			3.51	"			
Fallston			3.20	"			
St. George, Del	1884		4.40	7–8–9			
"			4.10	19–20			
District of Columbia	1886		3.12	30–31			
Fallston			4.65	27–31			
Emmitsburg			3.47	29–31			
McDonogh	1889		3.01	4			
Baltimore			2.71	23			
Dover, Del	1891		3.29	20–21			
Bachman's Valley	1896		2.80	19			

TABLE SHOWING EXCESSIVE PRECIPITATION.

APRIL.

Station.	Year.	Monthly rainfall, 10 inches or more.	Rainfall, 2.50 inches or more in 24 hours.		Rainfall of one inch or more in one hour.		
			Amt.	Date.	Amt.	Time.	Date.
Jewell	1889	12.20	2.50	6			
Baltimore			5.82	25–26			
Fort McHenry			5.00	25–26			
Jewell			7.50	25–26			
McDonogh			2.87	26			
Fenby	1894		3.30	10–11			
Woodstock			2.70	11–12			
Charlotte Hall	1895		3.67	8			
Fallston			2.75	8			
Jewell			3.00	8			
Pope's Creek			2.80	6–7			
Pocomoke City					1.59	0.40	27
Mardela Springs	1897		2.76	8–9			

MAY.

Station.	Year.	Monthly rainfall, 10 inches or more.	Amt.	Date.	Amt.	Time.	Date.
Fort McHenry	1876		3.02	15			
Woodstock	1878		3.10	21			
Dover, Del.	1879		2.80	3–4			
Emory Grove			5.00	15	5.00	3.00	15
Sandy Spring			4.28	16			
Woodstock			4.35	17–18	2.00	0.52	17
"			3.20	19			
St. John's Church	1881	12.30					
Emmitsburg	1882		2.50	28	2.50	2.15	28
Ocean City	1885		2.54	6–7			
Fallston			2.50	7			
Washington, D. C	1886	10.60	4.49	7–8			
Fallston			4.76	7–8			
Woodstock			4.00	7–8			
Baltimore			*4.17	6–8			
Fort McHenry			3.80	7–8			
McDonogh			3.13	7–8			
Cumberland	1887		3.79	7–8			
Baltimore	1889				1.20	1.00	20
Barren Creek Springs			4.12	20	2.25	1.00	20
Mt. St. Mary's		10.20	2.86	30			
Woodstock		10.34					
Kendall Green, D. C		10.73	3.12	31			
Washington, D. C		10.69	2.98	31			
Cumberland			3.75	31			
Fort McHenry		11.98	3.02	31			
Frederick			5.25	31			
Cumberland	1890				1.69	0.20	25
Fallston			3.00	25–26			
Jewell	1891		2.50	28			
Fallston	1894	10.41	3.42	5–6			
"			4.14	20–21			
Frederick			4.56	6			
New Market			3.00	6			

*2.99 fell on the 7th.

TABLE SHOWING EXCESSIVE PRECIPITATION.

MAY.—*Continued.*

Station.	Year.	Monthly rainfall, 10 inches or more.	Rainfall, 2.50 inches or more in 24 hours.		Rainfall of one inch or more in one hour.		
			Amt.	Date.	Amt.	Time.	Date.
Taneytown			2.90	18–19			
Darlington			3.40	19–20			
Milford, Del			2.55	20–21			
Newark, Del		12.67	4.34	20–21			
Wilmington, Del		11.99	6.99	20–21			
Bachman's Valley			3.45	20–21			
Boettcherville	1897		3.00	1–2			
District of Columbia			3.17	12–13			
College Park			2.60	13			
Taneytown			3.35	12–13			
Bachman's Valley			2.74	13–14			
Bachman's Valley	1898	12.29	4.40	7–8			

JUNE.

Station.	Year.	Monthly rainfall, 10 inches or more.	Amt.	Date.	Amt.	Time.	Date.
Cumberland	1876		3.30	17			
New Market			3.30	17–18			
Fort Foote	1877		2.88	27–28			
Sandy Spring	1878		3.64	19			
Baltimore	1880		2.66	11			
Cumberland			3.60	14			
St. John's Church	1881		2.50	7			
"			3.00	9			
Fallston			3.85	9			
Woodstock			3.00	20			
Washington, D. C			2.59	27			
Sandy Spring	1882				1.07	0.30	19
Fort McHenry	1883		3.38	26–27			
Fallston		10.21	4.22	26–27			
Baltimore			*3.28	26–27–28			
McDonogh			2.57	26–27			
Woodstock			3.15	26–27			
Receiving Reservoir, D. C	1884		3.19	11–12			
" "			3.25	14–15			
Washington, D. C			3.46	13–14			
Baltimore	1885		4.47	28			
McDonogh			2.48	28			
Fort McHenry			4.08	28			
Fort McHenry	1886		3.04	22			
Washington, D. C			4.16	22			
Baltimore			3.18	22			
Fort McHenry	1887		2.82	22			
Baltimore	1891				1.15	1.00	4
Cumberland			2.75	18	2.00	1.00	18
Cumberland	1892	10.08	4.64	4	4.64	1.00	4
Baltimore	1892				1.23	1.00	27
Mardela Springs	1894		4.47	6			
Easton			3.04	21	3.04	2.00	21

*2.66, 27th.

TABLE SHOWING EXCESSIVE PRECIPITATION.

JUNE.—*Continued.*

Station.	Year.	Monthly rainfall, 10 inches or more.	Rainfall, 2.50 inches or more in 24 hours.		Rainfall of one inch or more in one hour.		
			Amt.	Date.	Amt.	Time.	Date.
Sunnyside					1.00	1.00	27
Boettcherville	1895		2.50	13			
Chestertown			5.07	29			
Frederick	1896				1.05	1.00	8
Sharpsburg					1.08	0.48	8
Princess Anne					1.30	1.00	22
Laurel					1.00	1.00	28
Solomon's	1897		2.92	24	2.92	2.30	24
Mardela Springs	1898		2.68	18–19			
JULY.							
Dover, Del.	1874		2.54	4			
Woodlawn			4.45	11			
Baltimore	1875		2.70	15			
Fort McHenry			2.82	15–16			
District of Columbia	1876		4.12	30	1.00	1.00	30
Baltimore			3.12	30			
Milford, Del.	1877		2.80	27			
Baltimore					1.28	0.55	24
Sandy Spring	1878		2.84	19	2.00	1.00	19
Fort Foote			3.90	28–29			
District of Columbia			5.80	29–30			
District of Columbia	1879				1.73	1.15	26
Sandy Springs	1880				5.00	2.30	4
"					2.04	4.60	20
Baltimore			3.71	20			
Dover, Del.			2.50	20–21			
Fort McHenry	1884		3.54	11	3.54	1.45	11
Baltimore			3.75	11	3.75	1.43	11
"					1.40	1.15	31
Distributing Reservoir, D. C.			3.08	29–30			
Cape Henlopen, Del.	1885		2.61	26–27			
District of Columbia		10.63	2.72	2–3			
"			3.25	26			
Great Falls			2.67	2–3			
Fort McHenry			3.10	15			
Fallston		10.75	2.51	14–15			
"			3.25	25–26			
Baltimore	1887		2.76	21			
Cumberland			3.00	23			
District of Columbia	1888		2.98	9–10			
Jewell	1889	10.25	3.50	1–2			
McDonogh			2.53	1			
Baltimore		11.03	3.63	1–2	1.01	0.45	30
Barren Creek Springs		12.48	3.52	26–27			
Frederick			3.77	30			
District of Columbia			3.18	30–31			
Baltimore			4.02	30–31			

TABLE SHOWING EXCESSIVE PRECIPITATION.

JULY.—*Continued.*

Station.	Year.	Monthly rainfall, 10 inches or more.	Rainfall, 2.50 inches or more in 24 hours.		Rainfall of one inch or more in one hour.		
			Amt.	Date.	Amt.	Time.	Date.
Fallston		12.37					
Fort McHenry		10.18	3.50	30–31			
Gambrill's		13.04	4.18	30–31			
Leonardtown	1891	10.32	3.56	1–2			
Jewell		12.15	4.87	2			
District of Columbia			2.65	2			
Taneytown		10.20	2.98	1–2			
"			2.83	18			
Baltimore			2.59	8			
Barren Creek Springs		12.38	2.65	23–24			
Taneytown	1892				1.20	1.00	1
Seaford, Del	1893		3.50	31			
Cambridge			5.12	31	4.00	2.00	31
Cherryfields	1895		3.55	1			
Baltimore					1.05	1.00	5
Cherryfields	1896		3.74	6			
Princess Anne			2.61	6			
Laurel			2.50	7			
Sunnyside		15.27	3.20	20			
Baltimore					1.20	1.00	21
Sharpsburg			2.62	22–23			
Boettcherville			2.50	24			
Deer Park		13.65	4.10	24			
Grantsville		10.17	2.70	24			
Seaford, Del			3.00	27–28	3 00	2.15	27–28
Princess Anne	1897	11.38			2.05	1.00	3
New Market			2.85	12			
Baltimore					1.36	0.23	17
Chestertown			2.51	26			
Newark, Del			2.50	26–27			
Fallston			3.25	26–27			
Frederick			2.52	26–27			
Jewell		19.90	14.75	26–27			
Solomon's					1.17	0.50	28
Pocomoke City	1898		2.54	6	1.03	1.00	21
Grantsville			4.00	17	4.00	2.00	17
Solomon's					1.75	1.30	19
College Park					1.27	0.30	19
Denton			2.50	21			
Cherryfields			2.65	31			

AUGUST.

Station.	Year.	Monthly rainfall, 10 inches or more.	Rainfall, 2.50 inches or more in 24 hours: Amt.	Date.	Rainfall of one inch or more in one hour: Amt.	Time.	Date.
Fort Delaware, Del	1868				3.00	0.50	31
" "	1870		5.16	10–11			
Fallston	1872		11.55				
Baltimore	1873		4.36	13	1.30	1.00	10
Fort Delaware	1875	11.75					
Fort Foote		11.07					
St. Inigoes		11.35	2.50	2			

TABLE SHOWING EXCESSIVE PRECIPITATION.

AUGUST.—*Continued.*

Station.	Year.	Monthly rainfall, 10 inches or more.	Rainfall, 2.50 inches or more in 24 hours.		Rainfall of one inch or more in one hour.		
			Amt.	Date.	Amt.	Time.	Date.
Dover, Del			2.69	2–3			
Woodlawn		11.81			2.10	1.00	11
"					2.00	2.00	18
Dover, Del			2.50	12			
Baltimore					1.41	1.15	12
Annapolis		10.50					
Washington, D. C		12.93					
New Market		10.68	2.72	29			
Woodstock	1879						
Dover, Del			7.60	16–18			
"			2.50	25–26			
"		12.45					
"	1880		2.60	4–5			
Cumberland	1882		3.70	26–27			
St. George, Del	1883		3.20	2			
Sandy Spring					1.41	0.45	23
Fort McHenry			2.70	29			
Fort McHenry	1885		3.52	1–2–3			
Fallston		10.75	5.96	3			
Baltimore			3.35	3			
Distributing Reservoir, D. C			3.65	3–4			
Receiving Reservoir, D. C			2.95	3–4			
Great Falls			3.10	3–4			
Baltimore	1887				1.74	1.10	22
"	1888				1.12	1.00	5
"					1.03	1.00	8
Cumberland			2.68	21			
Washington, D. C	1889				1.05	1.00	6
Gambrill's			2.70	10	2.13	2.00	23
Baltimore	1890				1.96	1.10	21
Woodstock			2.80	21	2.80	2.00	21
Barren Creek Springs			2.56	25–26			
Fallston	1893		2.85	12	2.85	2.31	12
Solomon's					1.47	1.10	20
Cumberland			2.65	28			
"			2.60	28–29			
Boettcherville			3.00	28–29			
Fenby			3.40	28–29			
Milford, Del	1894		2.78	18			
Chestertown					1.85	0.30	15
Oldtown	1895				1.25	1.00	6
Millsboro, Del					1.34	1.00	15
Dover, Del					1.13	1.00	16
Milford, Del					2.10	1.55	16
Wilmington, Del					1.08	0.45	29
District of Columbia	1896				1.60	1.00	13
Boettcherville					1.00	1.00	13
Laurel					1.90	1.20	13
Deer Park	1897		3.20	4			
Millsboro, Del			3.11	10			
District of Columbia					1.95	0.47	10

TABLE SHOWING EXCESSIVE PRECIPITATION.

AUGUST.—*Continued.*

Station.	Year.	Monthly rainfall, 10 inches or more.	Rainfall, 2.50 inches or more in 24 hours.		Rainfall of one inch or more in one hour.		
			Amt.	Date.	Amt.	Time.	Date.
Fallston	......	......	3.23	10	.....	.....	.....
Green Spring Furnace	......	......	......	......	1.16	0.50	21
Mardela Springs	......	......	......	......	1.20	1.00	21
Newark, Del	1898	......	4.16	3–4	.....	.....	.....
Cumberland	......	......	3.00	4	.....	.....	.....
Frostburg	......	......	2.54	4	.....	.....	.....
Green Spring Furnace	......	......	2.52	4	.....	.....	.....
Westernport	......	......	2.88	4	.....	.....	.....
Woodstock	......	......	2.53	4	.....	.....	.....
District of Columbia	......	......	5.93	12	1.30	1.05	12
Baltimore	......	......	......	......	1.42	0.25	1
"	......	......	......	......	1.20	0.47	4–5
Grantsville	......	......	2.88	9	.....	.....	.....
Darlington	......	10.39	3.89	24	.....	.....	.....
College Park	......	......	2.76	12	.....	.....	.....

SEPTEMBER.

Station.	Year.	Monthly rainfall, 10 inches or more.	Amt.	Date.	Amt.	Time.	Date.
Fort Delaware	1868	19.85	10.70	3–4	.....	.....	.....
"	......	......	2.60	9	.....	.....	.....
District of Columbia	1874	......	5.66	15–16	.....	.....	.....
Fort Foote	......	......	4.12	15–16	.....	.....	.....
St. Inigoes	......	......	6.00	15–16	.....	.....	.....
Baltimore	......	......	3.15	16	.....	.....	.....
Milford, Del	......	11.05	......	......	.....	.....	.....
Dover, Del	1876	12.46	3.00	16–17	.....	.....	.....
Fort Foote	......	......	2.65	16–17	.....	.....	.....
Washington, D. C	......	10.81	3.37	17	.....	.....	.....
Baltimore	......	10.52	3.97	17	.....	.....	.....
Fallston	......	12.95	3.14	17	.....	.....	.....
"	......	......	2.50	23–24	.....	.....	.....
Fort Foote	......	......	2.65	16–17	.....	.....	.....
Fort McHenry	......	......	2.65	16–17	.....	.....	.....
Mt. St. Mary's	......	11.00	3.10	16–17	.....	.....	.....
New Market	......	10.64	......	......	.....	.....	.....
Woodstock	......	......	3.20	16–17	.....	.....	.....
Fort McHenry	1877	......	3.20	8	.....	.....	.....
Emory Grove	1878	......	3.00	4	.....	.....	.....
Woodstock	1882	......	2.70	10	.....	.....	.....
Emmitsburg	......	......	3.00	10–11	.....	.....	.....
Fort McHenry	......	......	2.87	22–23	.....	.....	.....
Washington, D. C	1885	......	3.48	4	.....	.....	.....
Fallston	......	......	4.61	15	.....	.....	.....
District of Columbia	1888	......	3.07	17	.....	.....	.....
Emory Grove	......	......	3.00	17	.....	.....	.....
Jewell	......	......	3.75	16	3.75	3.15	16
Baltimore	1891	......	4.00	5–6	.....	.....	.....
District of Columbia	......	......	3.85	6	.....	.....	.....
Fort McHenry	......	......	2.70	6	.....	.....	.....

TABLE SHOWING EXCESSIVE PRECIPITATION.

SEPTEMBER.—*Continued.*

Station.	Year.	Monthly rainfall, 10 inches or more.	Rainfall, 2.50 inches or more in 24 hours.		Rainfall of one inch or more in one hour.		
			Amt.	Date.	Amt.	Time.	Date.
Frederick	1892	......	4.53	13–14	4.07	4.00	13–14
Bachman's Valley	1894	......	3.28	6–7	......	......	......
Newark, Del	......	......	3.40	8	......	......	......
"	......	......	4.61	18–19	......	......	......
Millsboro, Del	......	......	2.96	19	......	......	......
Darlington	......	......	3.26	19	......	......	......
Milford, Del	1895	......	2.80	5–6	......	......	......
Bachman's Valley	......	......	2.80	6	......	......	......
Baltimore	......	......	4.76	6	......	......	......
Ellicott City	......	......	3.12	6	......	......	......
Fallston	......	......	3.15	6	......	......	......
Frederick	......	......	4.26	6	......	......	......
Westminster	......	......	4.48	6	......	......	......
Woodstock	......	......	4.10	6	......	......	......
Easton	......	......	......	......	1.33	1.00	19
Seaford, Del	1896	......	2.65	5–6	......	......	......
Baltimore	......	......	......	......	1.00	0.40	19
Chestertown	......	......	3.04	5	......	......	......
Mardela Springs	......	......	3.17	5–6	......	......	......
Princess Anne	......	......	3.17	6	......	......	......
Cumberland	......	......	3.91	29	......	......	......
Grantsville	......	......	2.50	29	......	......	......
Flintstone	......	......	4.90	29–30	......	......	......
Green Spring Furnace	......	......	3.55	29–30	......	......	......
Westernport	......	......	4.30	29	......	......	......
Jewell	1898	......	2.50	22–23	......	......	......

OCTOBER.

Station.	Year.	Monthly rainfall, 10 inches or more.	Amt.	Date.	Amt.	Time.	Date.
Fort Washington	1869	......	5.68	3–4	......	......	......
District of Columbia	1872	......	3.12	25	......	......	......
Fort Foote	......	......	2.65	25	......	......	......
District of Columbia	1873	......	2.86	19–20	......	......	......
Fort McHenry	......	......	2.74	19–20	......	......	......
Baltimore	......	......	3.42	20	......	......	......
Baltimore	1875	......	2.74	4	......	......	......
District of Columbia	......	......	......	......	1.40	1.00	23
Dover, Del	1877	......	3.30	3–4	......	......	......
District of Columbia	......	......	3.98	4	1.49	1.00	4
Emmitsburg	......	......	4.12	4	......	......	......
Fallston	......	......	5.09	4	......	......	......
New Market	......	......	5.14	4	......	......	......
Owings Mills	......	......	3.61	4	......	......	......
Woodstock	......	......	5.20	4	......	......	......
Fort Foote	......	......	3.16	5	......	......	......
Sandy Spring	......	......	2.50	8	......	......	......
Sandy Spring	1878	......	3.57	22	......	......	......
Woodstock	......	......	3.05	22–23	......	......	......
Fallston	......	......	2.60	22–23	......	......	......
Emory Grove	......	......	4.00	22	4.00	3.00	22

TABLE SHOWING EXCESSIVE PRECIPITATION.

OCTOBER.—*Continued.*

Station.	Year.	Monthly rainfall, 10 inches or more.	Rainfall, 2.50 inches or more in 24 hours. Amt.	Date.	Rainfall of one inch or more in one hour. Amt.	Time.	Date.
Emmitsburg			3.58	22–23			
Baltimore			2.75	23			
"			3.31	23			
Emmitsburg	1881		2.60	28–29			
"			3.52	30–31			
Woodstock	1885		3.10	2–3			
"		10.23	2.50	12–13			
Emmitsburg			2.55	20			
Receiving Reservoir, D. C		10.88					
Washington			3.44	29–30	1.20	1.00	29
Barren Creek Springs	1890		3.65	2			
Mt. St. Mary's			2.95	20–21			
Baltimore			3.04	23			
Frederick			2.39	23–24			
Fallston	1893		2.53	13			
District of Columbia			2.53	13–14			
Bachman's Valley			3.45	13–14			
Fenby			3.60	13–14			
Great Falls			2.60	13–14			
McDonogh			3.53	13–14			
Woodstock			3.60	13–14			
Valley Lee			3.00	23			
Darlington	1894		2.50	9			
Pocomoke City			2.60	9–10			
Woodstock			2.65	9–10			
Darlington	1896		3.08	12			
Baltimore					1.38	1.00	12
Mardela Springs			3.02	24			
Boettcherville	1898		2.50	18			
"			3.00	21			
Frostburg			2.95	18			
"			2.95	21			
Bachman's Valley			2.56	18–19			
Cumberland			3.21	21–22			
Mt. St. Mary's			2.63	21–22			

NOVEMBER.

Station.	Year.	Monthly rainfall, 10 inches or more.	Rainfall, 2.50 inches or more in 24 hours. Amt.	Date.	Rainfall of one inch or more in one hour. Amt.	Time.	Date.
Fort Delaware, Del	1868	10.40	2.90	1			
" "			3.00	20			
Dover, Del	1876	10.53	7.58	18–20			
Fallston	1877	10.27	2.60	8			
Mt. St. Mary's		11.00	2.67	8			
Sandy Spring			5.00	23–24			
Dover, Del			3.36	24			
District of Columbia			2.83	24	1.00	1.00	24
Baltimore			2.85	24			
Mt. St. Mary's			3.78	25			
New Market		10.00	3.78	25			

TABLE SHOWING EXCESSIVE PRECIPITATION.

NOVEMBER.—*Continued.*

Station.	Year.	Monthly rainfall, 10 inches or more.	Rainfall, 2.50 inches or more in 24 hours.		Rainfall of one inch or more in one hour.		
			Amt.	Date.	Amt.	Time.	Date.
Woodstock	......	......	3.51	26	......	......	......
Emory Grove	1878	13.00	3.00	23	......	......	......
"	......	......	4.00	27	......	......	......
Mt. St. Mary's	1881	......	2.94	1	......	......	......
Mt. St. Mary's	......	......	3.80	7–8	......	......	......
Galena	1889	10.17	......	......	......	......	......
Solomon's	1893	......	2.96	8–9	......	......	......
Valley Lee	......	......	3.37	9	......	......	......
Boettcherville	1896	......	3.00	4–5	......	......	......
Cumberland	......	......	2.68	4–5	......	......	......
Fallston	......	......	2.72	4–5	......	......	......
Flintstone	......	......	2.95	4–5	......	......	......
Darlington	1897	......	3.05	1	......	......	......
Newark, Del	......	......	3.02	1–2	......	......	......
Bachman's Valley	......	......	4.42	1–2	......	......	......
Fallston	......	......	2.58	1–2	......	......	......
Mt. St. Mary's	......	......	2.59	1–2	......	......	......
New Market	......	......	3.19	1–2	......	......	......
Port Deposit	......	......	3.25	1–2	......	......	......
Taneytown	......	......	3.47	1–2	......	......	......
Westminster	......	......	4.36	1–2	......	......	......
Woodstock	......	......	3.30	1–2	......	......	......

DECEMBER.

Station.	Year.	Monthly rainfall, 10 inches or more.	Amt.	Date.	Amt.	Time.	Date.
Fort Delaware, Del	1868	......	4.00	4–5	......	......	......
" "	......	......	3.30	8	......	......	......
" "	......	......	3.05	17	......	......	......
Baltimore	......	......	2.85	10	......	......	......
Newark, Del	......	......	3.70	16	......	......	......
Baltimore	1878	......	2.85	10	......	......	......
Fort McHenry	1879	......	3.16	13–14	......	......	......
Fallston	1883	......	2.52	23–24	......	......	......
"	1884	......	2.80	6	......	......	......
Galena	1888	......	2.70	10–11	......	......	......
Baltimore	......	......	2.56	16–17	......	......	......
Fort McHenry	......	......	3.16	17	......	......	......
McDonogh	......	......	3.02	17	......	......	......
Mt. St. Mary's	......	......	2.59	16–17	......	......	......
Fallston	......	......	4.95	17–18	......	......	......
District of Columbia	1891	......	......	......	1.09	1.00	24
Smithsburg	1898	......	4.01	4	......	......	......

In addition to the excessive precipitation given in the preceding tables, the following exceptionally heavy falls for shorter periods, as obtained from the register of a self-recording rain gauge, have oc-

curred at Baltimore. This registering gauge was installed at the Baltimore station November 22d, 1892, but on account of its liability to injury during freezing weather it is necessarily taken down during much of the winter season, and consequently the record therefrom is considerably broken from about the first of November to the middle of March:

	.25 inch or more in 5 minutes.	.50 inch or more in 10 minutes.
August 29, 1893	.25	....
July 8, 1893	.30	....
July 6, 1894	.25	....
September 8, 1894	.30	....
July 16, 1895	.30	.55
June 16, 1896	.35	.55
July 12, 1896	.30	....
September 19, 1896	.40	.75
May 21, 1897	.57	.67
June 4, 1897	.25	....
July 17, 1897	.40	.80
May 16, 1898	.39	.58
July 28, 1898	.30	.53
August 1, 1898	.46	.78

The most remarkable rainfall that has ever occurred in this state, as far as is known, is that at Jewell, Anne Arundel county, on July 27th, 1897. A full account was published in the monthly report of the Climate and Crop Service of the Maryland and Delaware Section for December of that year, from which the following is extracted:

"Probably the heaviest rainfall ever recorded in Maryland fell at Jewell during the eighteen hours from 6 p. m. July 26th to noon of the 27th, the amount measured being 14.75 inches. In a personal interview with the voluntary observer, Mr. J. Plummer, some of the details of the storm were learned.

"During the day of the 26th, the wind blew steadily from the northeast. A little before 6 p. m. a thunderstorm suddenly came up from the southwest, accompanied by a heavy downpour of rain, which continued with varying intensity through the entire night and until noon of the following day. The heaviest fall occurred between 6 p. m. and 9 p. m. of the 26th.

"The raingauge is of the standard 8-inch Weather Bureau pattern, holding, when filled, a 2-inch rainfall. In measuring the contents about noon of the 27th, the observer found the receiver filled and enough in the overflow to fill the receiver six times, with three-fourths of an inch left over, making a total of 14.75 inches. The exposure of the gauge is excellent, being on open ground, raised about 3 feet above the surface, and distant about 60 feet southeast from the two-story dwelling of the observer. Jewell is situated in the southern extremity of Anne Arundel County, near the Calvert County line, and about three miles from Chesapeake Bay. The

country about is generally rolling, with no marked contrasts in elevation. The vicinity of the station is about 160 feet above mean tide level.

"This extraordinary rainfall was confined within narrow limits. There was but one standard raingauge within a radius of twenty-five miles; there were however rough measurements made in the immediate neighborhood, which tallied closely with the record of Mr. Plummer. On a farm about three miles to the southwest a half barrel, with a depth of about 15 or 16 inches, which was empty before the rain, was completely filled by the rain. Making due allowance for the difference in diameter between top and base, the rainfall must have exceeded 12 inches. At another point distant about two miles some milk cans, with a depth of about 12 inches, were filled to overflowing. The top diameter of these cans was less than that of the base; which again would indicate a rainfall exceeding 12 inches. The roads in the vicinity of Jewell were gullied in places to the depth of 4 and 5 feet by the rain. The lowlands were flooded, crops were destroyed and fences were carried away. The level of Lyons Creek was higher than it had ever been observed before.

"The daily weather maps of the United States Weather Bureau for July 26th, 27th, and 28th, show an irregular and shallow area of low pressure, nearly stationary over the Lower Lake Region and Middle Atlantic States, together with much cloudiness and rain. Pressure areas over the entire country were much broken up, with but slight differences between the highest and lowest barometer readings. At 8 p. m. of the 26th, during the time of heaviest precipitation, the lowest pressure was recorded at Cleveland, Ohio, 29.68 inches, bringing Jewell within the southeast quadrant of the storm area, and about 500 miles from the center. The barometer was highest (30.10 inches) over the New England States to the Northeast, and in Missouri (30.00 inches) to the Southwest. At Baltimore, Philadelphia, and Washington the prevailing winds were from the east and northeast on the 26th, 27th, and 28th. During these days rain fell to the depth of over three inches at the following stations in the eastern portions of Maryland and Pennsylvania:

MARYLAND.		PENNSYLVANIA.	
Stations.	Amount in inches.	Stations.	Amount in inches.
Annapolis	3.15	Browers Lock	3.06
Baltimore	3.10	Dyberry	4.45
Fallston	3.65	Honesdale	3.22
Frederick	3.07	Philadelphia	3.70
Jewell	14.75	Pottstown	3.34
Solomon's	3.84	Reading	3.15
Taneytown	3.38	Shawmont	3.39
Van Bibber	3.75		

The following are among some of the most remarkable rainfalls that have occurred in the United States, and are given for comparison:

Probably the heaviest rainfall ever recorded in the United States within twenty-four hours occurred at Alexandria, Louisiana, June 15-16, 1886, when 21.4 inches fell. A few other extraordinary showers are: Tridelphia, Pa.,

July 19, 1888, 6.9 inches in 55 minutes; Philadelphia, Pa., July 26, 1887, 0.62 inches in 7 minutes; Philadelphia, Pa., August 3, 1898, 5.43 inches in 1 hour and 44 minutes; Newton, Pa., August 5, 1843, 5.5 inches in 40 minutes, and 13 inches in 3 hours; Concord, Pa., 16 inches in 3 hours; Brandywine Hundred, Pa., 10 inches in 2 hours; Wilmington, Del., July 29, 1839, 15 inches in 24 hours; Washington, D. C., June 27, 1881, 2.34 inches in 37 minutes, and July 26, 1885, 0.96 inches in 6 minutes; St. Louis, Mo., August 15, 1848, 5.05 inches in 1 hour; New York City, May 22, 1881, 1.15 inches in 10 minutes.

COMPARATIVE RAINFALL DATA.

The conditions of rainfall that prevail in Maryland are closely approximated generally throughout New England, the Middle Atlantic states, the Ohio valley, central Oregon and Washington, England, Iceland, large portions of central Europe, and portions of India and China. The following tables show places in various portions of the United States and in foreign countries having an annual rainfall, and a rainfall during the crop season from April to September, inclusive, agreeing very nearly with the rainfall conditions at Baltimore:

ANNUAL RAINFALL SAME AS AT BALTIMORE.

STATIONS.	Latitude.	Longitude.	Elevation.	Inches.
Baltimore, Md.	38° 18′ N.	76° 37′ W.	123 ft.	43.3
Portland, Ore.	45° 32′ N.	122° 43′ W.	153 "	46.2
St. Louis, Mo.	38° 38′ N.	90° 12′ W.	567 "	40.8
Cincinnati, Ohio	39° 06′ N.	84° 30′ W.	628 "	42.1
Indianapolis, Ind.	39° 46′ N.	86° 10′ W.	823 "	42.2
Cairo, Ill.	37° 00′ N.	89° 10′ W.	359 "	42.6
Lynchburg, Va.	37° 25′ N.	79° 09′ W.	685 "	43.1
New York City	40° 43′ N.	74° 00′ W.	314 "	44.7
Des Moines, Iowa	41° 35′ N.	93° 40′ W.	849 "	42.7
Puebla, Mexico	19° 03′ N.	98° 11′ W.	7115 "	46.8
Havana, Cuba	23° 09′ N	82° 23′ W.	63 "	46.4
Rio de Janeiro, Brazil	22° 54′ S.	43° 08′ W.	209 "	44.5
Triest, Austria	45° 38′ N.	13° 46′ E.	85 "	43.4
Lausanne, Switzerland	46° 30′ N.	6° 37′ E.	1690 "	40.4
Shanghai, China	31° 19′ N.	121° 16′ E.	23 "	43.3

RAINFALL DURING CROP SEASON SAME AS AT BALTIMORE.

STATIONS.	Latitude.	Longitude.	Elevation.	Crop season. Apr.–Sep.	Inches.
Baltimore, Md.	38° 18′ N.	76° 37′ W.	123 ft.	23.8 ft.	43.3
New Haven, Conn.	41° 18′ N.	72° 56′ W.	24 "	23.2 "	45.8
New York City	40° 43′ N.	73° 58′ W.	52 "	23.3 "	44.7
Louisville, Ky.	38° 15′ N.	85° 45′ W.	432 "	23.9 "	47.2
Ames, Iowa	42° 00′ N.	93° 38′ W.	926 "	23.1 "	31.1
St. Louis, Mo.	38° 37′ N.	90° 12′ W.	481 "	23.8 "	40.8
Omaha, Neb.	41° 16′ N.	95° 56′ W.	1040 "	23.8 "	31.4

SNOWFALL.

Snowfall never fails completely in Maryland even in the warmest winters, although it may be reduced to insignificant proportions except in the mountains. The average monthly amounts for the various climatic divisions of the state are shown in the table below:

AVERAGE DEPTH OF SNOW IN INCHES.

	Jan.	Feb.	Mar.	Apr.	May.	Nov.	Dec.
Western section........	12.0	8.9	9.2	3.1	1.8	3.2	5.2
N. Central section......	5.1	5.1	6.6	2.0	...	5.6	2.4
Southern section	5.4	4.0	1.0	1.4	...	2.5	2.3
Eastern section	4.6	4.1	...	1.5	...	2.5	1.9
Entire state	6.6	5.7	5.0	1.4	0.4	3.7	2.6

The succeeding table gives the total snow depths for every month in which any occurred at Baltimore since 1883.

TOTAL SNOW DEPTHS IN INCHES SINCE 1883.

Year.	Jan.	Feb.	Mar.	Apr.	Oct.	Nov.	Dec.
1883........	10.7	0.0	6.9	0.0	0.0	0.6	0.0
1884........	14.2	0.0	8.7	8.0	0.0	0.0	3.8
1885........	1.9	17.2	5.9	2.0	0.0	0.0	0.0
1886........	13.0	15.3	2.0	0.0	0.0	0.0	10.2
1887........	2.5	5.0	6.8	1.1	0.0	0.0	12.0
1888........	8.8	3.9	7.4	0.0	0.0	1.1	T
1889........	2.6	5.3	T	T	T	0.0	0.0
1890........	0.1	2.5	2.3	T	T	T	10.6
1891........	1.3	3.5	20.5	0.0	0.0	T	T
1892........	14.5	4.2	25.6	T	0.0	2.2	4.3
1893........	8.1	11.7	4.0	0.0	0.0	0.2	8.1
1894........	1.0	11.7	T	5.0	0.0	T	3.0
1895........	5.0	9.3	0.6	0.0	T	0.0	0.2
1896........	1.0	2.8	13.8	T	0.0	3.0	3.2
1897........	4.7	0.7	T	0.0	0.0	T	2.6
1898........	5.4	T	2.4	0.1	0.0	9.7	0.6
1899........	5.3	33.9	1.6	T	0.0	0.0	0.0

Some of the heaviest continuous snowfalls of this period were: 6.1 inches in January, 1886; 6.0 inches in January, 1892; 8.7 inches in February, 1893; 6.0 inches in February, 1894; 16.5 inches in March, 1892; 6.4 inches in March, 1896; 5.0 inches in April, 1884; 4.5 inches in November, 1898; 11.3 inches in December, 1887; 9.0 inches in December, 1890. There were two periods of continuous heavy snowfall in February, 1899; the first gave a depth of 11.7

inches, and the second, 21.4 inches. This latter storm gave the greatest accumulated depths of which there is any record, and combined with that previously on the ground, measured between two and three feet over the greater portion of the state.

HAIL.

Hailstorms are not found to be more frequent in one part of Maryland than another. They have occurred in every part of the state, and are not frequent, the records generally showing an average of two to four each year for a single station. They are most frequent from May to August. The following shows the total number of days in each month for the five years, 1893-97, on which hail fell at one or more stations in Maryland:

Jan.	Feb.	Mar.	Apr.	May.	Jun.	July.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual.
1	0	5	8	17	12	23	16	6	5	4	0	97

THUNDERSTORMS.

Thunderstorms occur in all portions of the state, and there is no evidence that they are more frequent in any one section than another. The months of greatest frequency are May to August. The following table summarizes the thunderstorm conditions for the state for the past seven years, showing for each month the average number of days with thunderstorms within the limits of the state, also the greatest number of days and the least number of days with thunderstorms in any month. The data given are based on records made at about fifty stations located in all parts of the state.

TABLE SHOWING FREQUENCY OF THUNDERSTORMS.

	Jan.	Feb.	Mar.	Apr.	May	Jun.	July	Aug.	Sep.	Oct.	Nov.	Dec.	Annual.
Average number of days	2	1	7	8	18	18	19	17	10	8	8	1	109
Greatest number of days	3	4	10	10	24	21	24	19	14	7	6	3	117
Least number of days	0	0	5	5	10	15	15	15	5	0	1	0	90

The following table covers the record of thunderstorms at Baltimore for the past twenty-eight years:

	Jan.	Feb.	Mar.	Apr.	May	Jun.	July	Aug.	Sep.	Oct.	Nov.	Dec.
Average number of days ..	0.2	0.4	0.5	1.0	3.3	5.2	5.4	3.6	1.2	0.4	0.1	0.2
Greatest number of days ..	1	1	4	3	7	9	11	9	4	2	1	1
Least number of days ..	..	..	1	1	1	1	1	1	0	0	..	..

LOSS OF LIFE AND PROPERTY BY LIGHTNING.

The following facts in regard to the loss of life and property by lightning in Maryland have been obtained from Bulletin No. 26, of the U. S. Department of Agriculture, Weather Bureau, just issued: During the three years, 1896-1898, there were nine deaths in Maryland by lightning as against thirty-five in Virginia, six in West Virginia and seventy-one in Pennsylvania for the same period. Of the Middle Atlantic States, which taken together average five deaths per million population per year, Maryland has the smallest ratio of deaths by lightning, being three per million people, while Virginia has seven and Delaware six.

During the six years, 1890 to 1897, there were 143 barns, 41 dwellings, 1 church, 2 factories, and 6 buildings of other kinds, or 193 in all, set on fire by lightning, in this state. During 1898 there were 22 buildings struck and damaged by lightning, occasioning a loss of $10,785; also 5 head of cattle and 3 horses were killed in the field.

SEVERE STORMS.

Maryland is seldom visited by storms of such severity as to cause much loss of life or property. Those of greatest violence have their origin in the West Indies and move northward along the coast, and are usually more destructive in their effects over the South Atlantic states and along the New England coast than on the Middle Atlantic seaboard—a fact already mentioned under the heading of storm types.

According to General Greely[1] the recorded instances of tornadoes in Maryland are only about five since 1794, while the number reaches

[1] American Weather, Dodd, Mead & Co., New York, 1888.

thirty over portions of Georgia on the south and from fifteen to thirty in the vicinity of the Lakes on the north and northwest. Local thunderstorms and hailstorms are occasionally quite severe, but on the whole the state lies in an area less frequently visited by severe general storms than almost any other east of the Mississippi river.

On March 11-12, 1888, during the prevalence of the general blizzard over the Middle and North Atlantic states, severe weather conditions were experienced generally throughout Maryland. At Baltimore the storm ended during the night of the 11th-12th and was followed by cold weather, the wind coming from the northwest throughout the 12th causing the lowest tide for many years, the bottom of the harbor being exposed in many places. The tide in the harbor did not regain its normal height until the 16th. Reports from the surrounding country and from Chesapeake bay showed the storm to have been very severe, and many vessels arriving on the 14th and 15th reported having experienced remarkably rough weather.

A very destructive wind, rain and hail storm occurred in Baltimore and vicinity on April 27, 1890. Thousands of windows and skylights were broken and many houses unroofed. Estimated damage was from $60,000 to $100,000.

One of the most severe storms of recent years was that of September 29, 1896. This storm was very destructive to timber, uprooting or snapping off thousands of trees throughout the state. Of the more populous centers, Washington City suffered most, where the wind reached a maximum velocity of sixty-six miles per hour from the southeast; several large buildings were blown down, one life was lost, and a general loss of property occasioned to the amount of $400,000.

On July 17, 1897, Baltimore was visited by a severe local storm, the lightning, wind and rain doing much damage to city property.

On December 4, 1898, during the passage of a west Gulf storm, considerable damage, amounting to about $100,000, was done in Baltimore. The wind blew at the rate of sixty miles per hour for four consecutive minutes, during which time over two hundred houses were partly or wholly unroofed, and innumerable signs, awnings and shutters were blown away or wrecked.

The heavy snow storm and blizzard that reached its greatest severity on February 13, 1899, has been described elsewhere.

RELATIVE HUMIDITY.

The ratio of the amount of moisture in the air to the amount it would contain at the point of complete saturation is called the relative humidity. This condition is measured in terms of percentage, complete saturation being 100 per cent. There are no reliable records of relative humidity in Maryland except those made at Baltimore and Washington. The figures below give the average monthly relative humidity at the former place for the past 28 years, together with the greatest and least monthly averages observed during that period:

	Jan.	Feb.	Mar.	Apr.	May	Jun.	July	Aug.	Sep.	Oct.	Nov.	Dec.	Year
Average........	71	68	65	61	64	66	66	70	72	69	70	69	68
Greatest	74	78	74	70	70	74	78	80	81	75	76	75	81
Least	62	59	54	50	50	60	60	61	67	56	58	59	50

CLOUDINESS.

The average cloudiness for Maryland is between 50 and 60 per cent. of the total number of hours of possible sunshine. The difference in average cloudiness is not great in any part of the state, as will be seen from the following tables, showing the average number of clear, partly cloudy and cloudy days for the past seven years:

NUMBER OF CLEAR DAYS OR DAYS WITH THIRTY PER CENT. OR LESS OF CLOUDINESS.

	Jan.	Feb.	Mar.	Apr.	May	Jun.	July	Aug.	Sep.	Oct.	Nov.	Dec.
Western section	9.2	9.2	11.7	10.7	12.0	14.2	14.8	17.1	18.1	16.0	10.9	10.8
N. Central section ...	11.4	11.1	12.9	12.1	11.9	14.9	15.6	17.8	17.7	16.7	13.5	14.0
Southern section	11.6	11.3	11.3	12.2	12.7	13.1	14.2	17.1	17.7	17.1	11.9	13.6
Eastern section......	11.8	12.6	12.3	13.1	13.1	13.1	15.3	17.3	17.2	16.6	13.5	13.7
Entire state.........	11.1	11.1	12.3	12.4	13.9	13.7	15.3	18.1	17.3	16.4	12.6	13.7

NUMBER OF FAIR DAYS OR DAYS WITH FORTY TO SEVENTY PER CENT. OF CLOUDINESS.

	Jan.	Feb.	Mar.	Apr.	May	Jun.	July	Aug.	Sep.	Oct.	Nov.	Dec.
Western section.....	8.0	8.1	8.9	7.9	10.7	9.4	9.9	8.6	6.6	7.7	7.7	9.2
N. Central section...	8.5	7.8	8.8	9.4	10.5	10.2	10.5	9.2	7.8	6.7	7.7	8.2
Southern section	7.8	6.1	8.4	8.5	9.1	10.6	10.1	8.7	6.5	6.2	9.0	8.2
Eastern section......	8.3	6.5	9.8	8.8	11.0	12.0	10.3	10.0	7.4	7.4	8.1	9.9
Entire state	8.5	7.3	7.6	8.4	10.8	10.5	9.9	8.6	7.1	7.6	7.6	8.0

NUMBER OF CLOUDY DAYS OR DAYS HAVING EIGHTY TO ONE HUNDRED PER CENT. OF CLOUDINESS.

	Jan.	Feb.	Mar.	Apr.	May	Jun.	July	Aug.	Sep.	Oct.	Nov.	Dec.
Western section.....	13.6	11.0	10.3	12.3	9.1	5.8	5.8	5.7	4.9	7.4	11.5	10.7
N. Central section...	11.3	9.1	9.6	7.1	8.6	6.2	5.2	4.2	5.8	7.5	9.5	10.3
Southern section....	11.8	10.8	11.0	8.8	8.7	6.1	7.8	5.4	5.8	7.3	9.7	9.3
Eastern section	10.9	9.3	9.0	8.1	6.9	4.4	5.3	4.0	5.2	6.9	8.4	8.5
Entire state	12.0	10.0	10 0	8.8	10.8	5.3	5.8	4.9	5.5	5.1	9.8	9.3

In the same way the following table gives:

CLOUDINESS AT BALTIMORE DURING THE PAST TWENTY-EIGHT YEARS.

	Jan.	Feb.	Mar.	Apr.	May	Jun.	July	Aug.	Sep.	Oct.	Nov.	Dec.	Year
Clear.													
Average	8	8	9	9	10	10	10	11	12	12	10	9	118
Greatest	15	15	14	16	15	17	17	19	22	23	16	16	....
Least........	4	3	4	4	3	2	2	2	6	7	2	4	....
Partly.													
Average	12	11	12	12	11	13	13	13	11	11	10	12	141
Greatest	18	18	17	17	19	25	21	17	10	16	19	20	....
Least........	5	5	5	8	5	6	9	6	4	4	6	5	....
Cloudy.													
Average	11	9	10	9	10	7	8	7	7	8	10	10	106
Greatest	16	16	16	16	17	14	14	17	15	13	16	18	....
Least........	3	2	5	6	5	1	3	2	0	0	4	5	....

AVERAGE PERCENTAGE OF SUNSHINE AT BALTIMORE.

Jan.	Feb.	Mar.	Apr.	May.	Jun.	July	Aug.	Sep.	Oct.	Nov.	Dec.	Year
45	48	47	50	52	57	53	56	58	55	50	48	52

WINDS.

The prevailing winds in Maryland are northwesterly in winter, and during the summer months blow from a southerly direction, more generally from the southwest. The following tables show the prevailing wind direction for the several divisions for the past seven years, and for Baltimore for the past twenty-eight years:

PREVAILING WINDS.

	Jan.	Feb.	Mar.	Apr.	May	Jun.	July	Aug.	Sep.	Oct.	Nov.	Dec.
Western section	NW.	NW.	SW.	Var.	SW.	Var.	Var.	SW.	Var.	Var.	Var.	SW.
N. Central section...	NW.	NW.	NW.	NW.	Var.	Var.	SW.	SW.	Var.	NW.	NW.	NW.
Southern section	NW.	NW.	NW.	Var.	Var.	Var.	SW.	SW.	Var.	NW.	NW.	NW.
Eastern section......	NW.	NW.	NW.	Var.	Var.	SW.	SW.	Var.	Var.	NW.	NW.	NW.
Entire state.........	NW.	NW.	NW.	NW.	Var.	Var.	SW.	SW.	Var.	NW.	NW.	NW.

PERCENTAGE OF WINDS FROM EACH DIRECTION AT BALTIMORE.

	Jan.	Feb.	Mar.	Apr.	May	Jun.	July	Aug.	Sep.	Oct.	Nov.	Dec.	Year
N.......	13	12	12	11	11	10	12	13	15	15	12	12	12
NE	12	14	13	13	12	9	7	13	4	12	10	10	12
E.......	8	8	7	8	9	8	6	8	8	6	6	7	8
SE......	7	9	7	9	18	14	12	12	13	11	9	7	11
S........	7	7	6	9	12	15	15	15	12	9	8	7	10
SW......	11	7	8	8	10	16	16	13	11	11	10	14	11
W	16	13	11	12	9	12	12	9	9	10	14	15	12
NW.....	21	25	28	21	16	14	14	13	13	19	24	22	19
Calm....	5	6	5	5	4	3	4	4	5	7	6	6	5

The direction of the wind depends upon the relative positions of the pressure areas with respect to each other and to Maryland. The velocity of the wind is determined by the intensity of the atmospheric disturbances. The only satisfactory records of the wind veloc-

ities for the state are those that have been made at Baltimore and Washington. The average monthly daily and hourly velocities of the wind, in miles, for Baltimore during the past twenty-eight years are given in the table below:

AVERAGE MONTHLY, DAILY AND HOURLY WIND MOVEMENT AT BALTIMORE.

Average.	Jan.	Feb.	Mar.	Apr.	May	Jun.	July	Aug.	Sept.	Oct.	Nov.	Dec.
Monthly	4609	4506	5499	5038	4636	4284	4147	3787	3931	4376	4413	4492
Daily.............	149	161	177	168	150	143	134	122	131	141	147	145
Hourly	6.2	6.7	7.4	7.0	6.2	6.0	5.6	5.1	5.5	5.9	6.1	6.0

BAROMETRIC PRESSURE.

The actual conditions of barometric pressure, as shown by the readings of a mercurial or aneroid barometer, depend mainly upon elevation. The readings will be highest at sea-level and lowest in the mountains, and, with the atmosphere in a quiescent state, the range in Maryland will be about three inches. In recording barometric observations, however, it is customary to reduce the readings to a standard of elevation and temperature—that of sea-level and a temperature of 32° Fahrenheit. Comparative statements regarding the barometric pressure are usually considered to refer only to the variations due to the passage of atmospheric disturbances. The following table shows the average and extreme readings of the barometer at Baltimore during the past twenty-eight years, reduced to standard conditions of elevation and temperature:

AVERAGE, HIGHEST AND LOWEST BAROMETRIC PRESSURE REDUCED TO SEA-LEVEL AT BALTIMORE.

	Jan.	Feb.	Mar.	Apr.	May	Jun.	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
Average	30.14	30.12	30.05	30.05	29.98	30.00	30.00	30.02	30.10	30.08	30.13	30.14	30.07
Highest ever recorded.	30.98	30.90	30.74	30.64	30.46	30.50	30.51	30.36	30.53	30.66	30.84	30.92	30.98
Lowest ever recorded.	29.00	29.28	29.15	29.23	29.58	29.52	29.63	29.44	29.51	29.11	29.41	29.24	29.00

In the wind barometer table prepared by Professor Garriott, and reproduced in the chapter on Meteorology, the pressures given are those for sea-level and a temperature of 32°. Any one having an aneroid barometer, compensated for temperature, can apply the following comparative values to advantage in testing the merits of the table.

Height.	Barometric reading in inches.	Height.	Barometric reading in inches.
Sea-level	30.00	1600 feet	28.29
200 feet	29.78	1800 "	28.08
400 "	29.56	2000 "	27.88
600 "	29.34	2200 "	27.67
800 "	29.13	2400 "	27.47
1000 "	28.92	2600 "	27.27
1200 "	28.71	2800 "	27.07
1400 "	28.50	3000 "	26.87

Conclusion.

Professor Cleveland Abbe's article has presented in a comprehensive manner an account of the various meteorological instruments used, and the historical sketch by Dr. Fassig thoroughly describes the past operations of the U. S. Weather Bureau and State Weather Service in Maryland. It would therefore be superfluous to do more than invite attention to their interesting reports which appear elsewhere in this volume. It will not be amiss, however, to give a brief summary of the active meteorological work that is being carried on in the state at the present time. This work can be classified into three heads, (1) weather forecasts and their distribution, (2) regular voluntary meteorological stations, and (3) special voluntary meteorological stations.

First. Local forecasts of expected weather are made for the ensuing 36-hour period in Baltimore, and distributed throughout the city and vicinity. These forecasts are based upon meteorological observations taken at the Weather Bureau stations scattered throughout the United States and Canada. These observations are taken at 8 A. M. and 8 P. M. respectively. The messages coming in are received at the Baltimore station by 9.15 A. M. and P. M. each day. From the A. M. reports a synoptic chart is prepared and from this chart the forecasts are deduced. By 1 P. M. the forecasts have

been widely distributed over the city and vicinity. For this purpose the telephone and mail are extensively used. Weather and temperature forecasts for the whole state are made twice daily at the Central

Fig. 61.—Voluntary observer's station.

Office at Washington and telegraphed to authorized points, where the recipient, usually the postmaster, displays the flag signals for weather and temperature. Quite a number of the displaymen repeat the fore-

cast on postal cards to postoffices in their locality that can be reached through the mail on the same day. The Washington office also issues forecasts for severe storms, cold waves, heavy snows and blizzards, which are given a special dissemination. The storm signals for the benefit of maritime interests are displayed at the port in Baltimore, at Annapolis and at Oxford.

Second. In this division are classed the voluntary meteorological and crop reporting stations. The meteorological stations are equipped with maximum and minimum thermometers and rain gauges. In most instances the thermometers are located in standard instrument shelters. The voluntary observers render monthly reports giving for each day the highest and lowest temperature, the rainfall, the condition of the weather—whether cloudy, fair, etc.—and special phenomena, such as thunderstorms, auroras, ice, frosts, snows and fogs.

At the crop reporting stations, the correspondents report weekly during the crop-growing season from about April 1st to October 1st upon the condition and development of all crops in their neighborhood. A number of the crop correspondents also have rain gauges and report the daily rainfall. The crop reporting stations have been established in all portions of Maryland and Delaware, and the distribution has been so effected that their reports will give an average of the conditions that have prevailed over the several localities. The crop information received from them is summarized and compiled, and appears weekly during the growing season in the Climate and Crop Bulletins issued from the Baltimore office.

Third. Under this head is included a number of special meteorological stations established for the purpose of original research and investigation as to the influence of certain natural physiographic features of the state on the climate, such as the Chesapeake Bay on the Coastal Plain, the enclosing mountain ranges on the climate of the Hagerstown Valley, etc.

The location of these various coöperating stations is shown in Plate XXXVII, and the nature of the work carried on at each station is represented by the appropriate symbol.

In the preceding pages there has been given a brief summary of

the general meteorological and climatic conditions of Maryland, as far as these are at present known. A number of very important features are still obscure. The especial adaptability of both climate and soil in certain sections to a particular crop is understood in a general way, and the knowledge has been practically applied in the production of truck, tobacco, peaches, etc., in the districts most favoring each industry. Still in many cases a better presentation of climatic facts would doubtless lead to an increased production of certain crops in districts peculiarly adapted to their growth. The experience of the past winter shows that the severe February freeze practically destroyed the peach crop of 1899, but that a few favored localities will give fair yields; this brings up a consideration of the problem of water influences, and it would be of interest and value to know, not only to what extent these have protected the crop, but the exact manner in which the protection was afforded, and whether such protection was to a certain degree accidental or can always be relied upon. A further and more intimate knowledge of all features of *local* climate is also required in the interests of health. In this connection the statements that have recently been made to the effect that the Eastern Shore has a climate especially congenial to pulmonary diseases, and that malaria is gradually being eliminated there, should, if possible, be scientifically confirmed and the reason clearly shown. The relations of the character of the soil to its moisture requirements should be defined for all sections, in order that the unconditioned figures of rainfall for the various portions of the state may obtain a new and truer value. Some of these problems fall naturally within the scope of State Weather Service work, while others belong more properly to such departments as the Division of Soils and Agricultural Experiment Stations. All will be investigated with a view to their solution as soon as the necessary data can be collected in sufficient detail.

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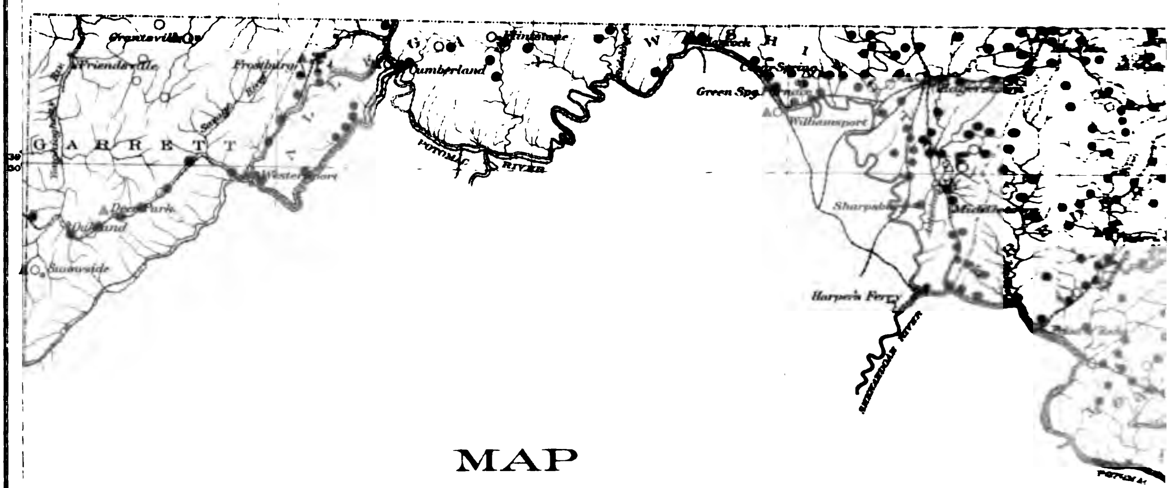


MAP

SHOWING THE LOCATION

OF THE

METEOROLOGICAL, DISPLAY AND CROP STATIONS

IN

MARYLAND

INCLUDING

DELAWARE AND THE DISTRICT OF COLUMBIA

SCALE
1:1,250,000. 20 Miles = 1 Inch

0 5 10 20 40 60

MARYLAND STATE WEATHER SERVICE

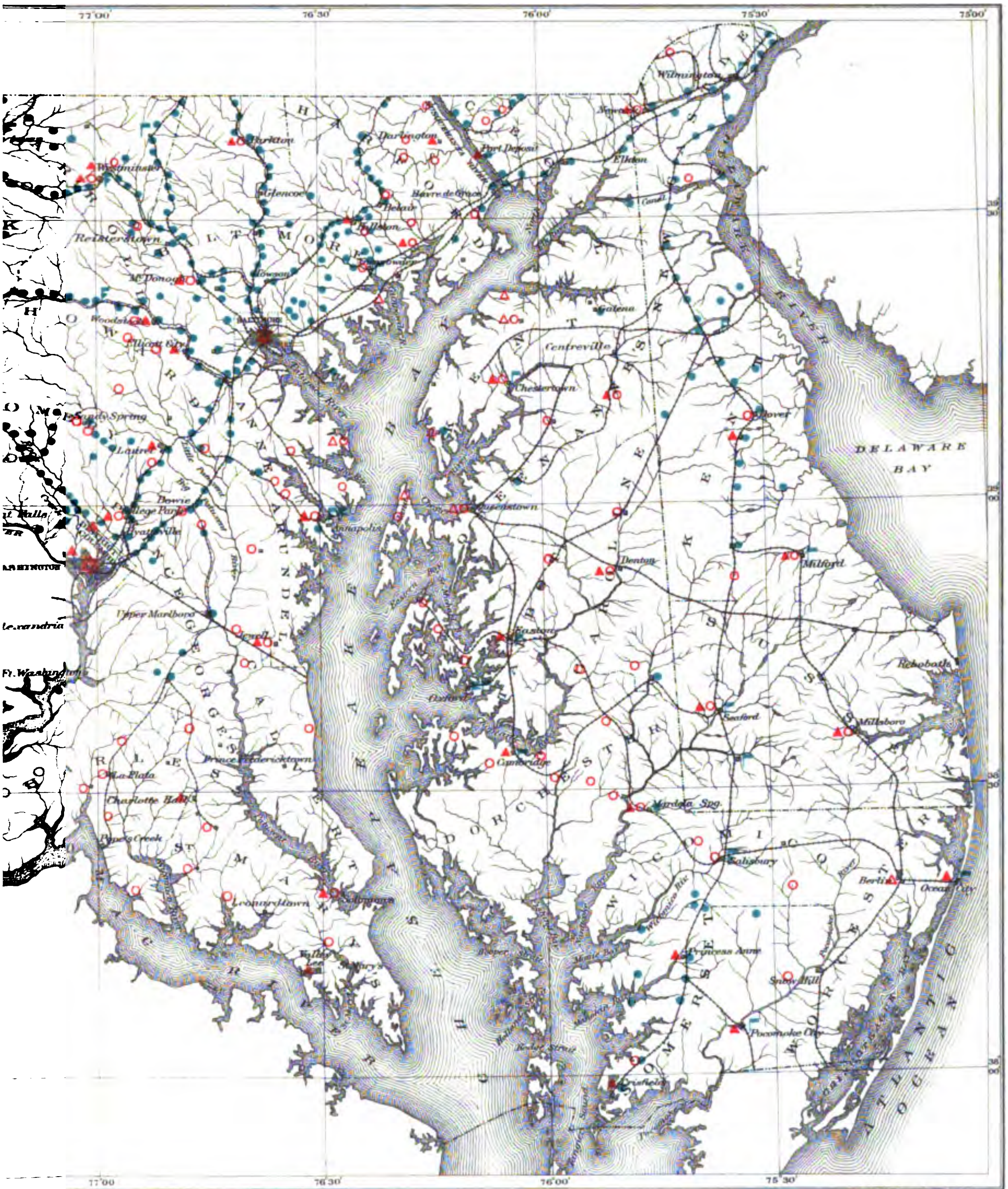
WM. B. CLARK, DIRECTOR

F. J. WALZ, METEOROLOGIST

1899

LEGEND

✡ FIRST ORDER WEATHER BUREAU STATION	WIND SIGNAL DISPLAY STATION (TELEGRAPHIC)
▲ REGULAR VOLUNTARY STATION	FORECAST DISPLAY AND DISTRIBUTING STATION (TELEGRAPHIC)
△ SPECIAL VOLUNTARY STATION	FORECAST DISPLAY STATION (TELEGRAPHIC)
○ CROP REPORTING STATION	● FORECAST DISPLAY STATION (MAIL)



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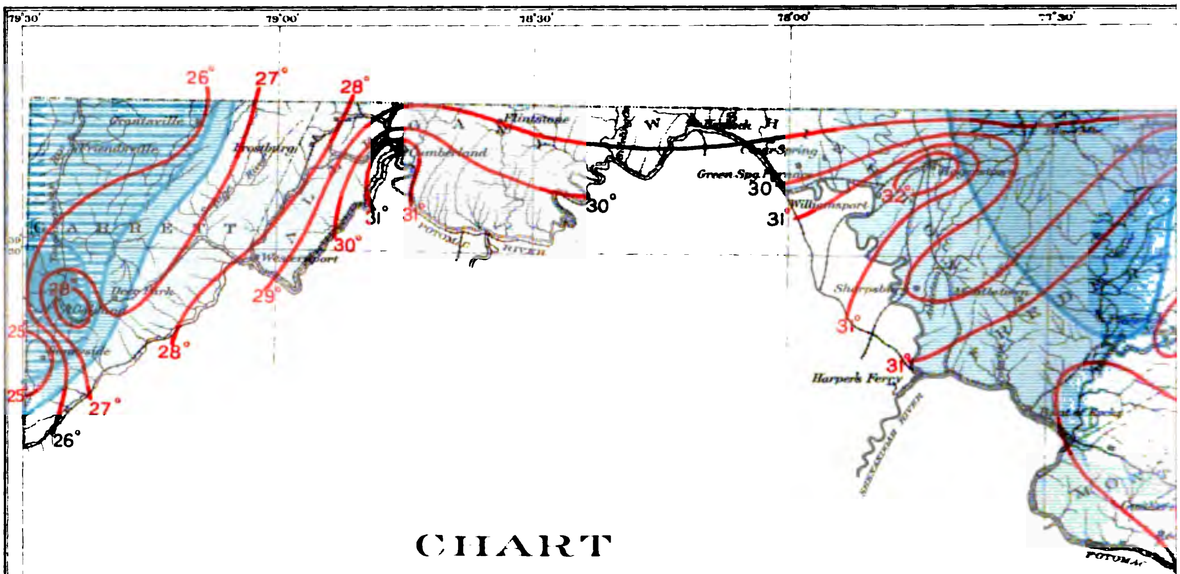


CHART

SHOWING THE

NORMAL TEMPERATURE AND PRECIPITATION

FOR

MARYLAND

INCLUDING

DELAWARE AND THE DISTRICT OF COLUMBIA

JANUARY

SCALE

1:1,250,000. 20 Miles = 1 Inch

0 5 10 20 40 60

MARYLAND STATE WEATHER SERVICE

WM. B. CLARK, DIRECTOR

F. J. WALZ, METEOROLOGIST

1899

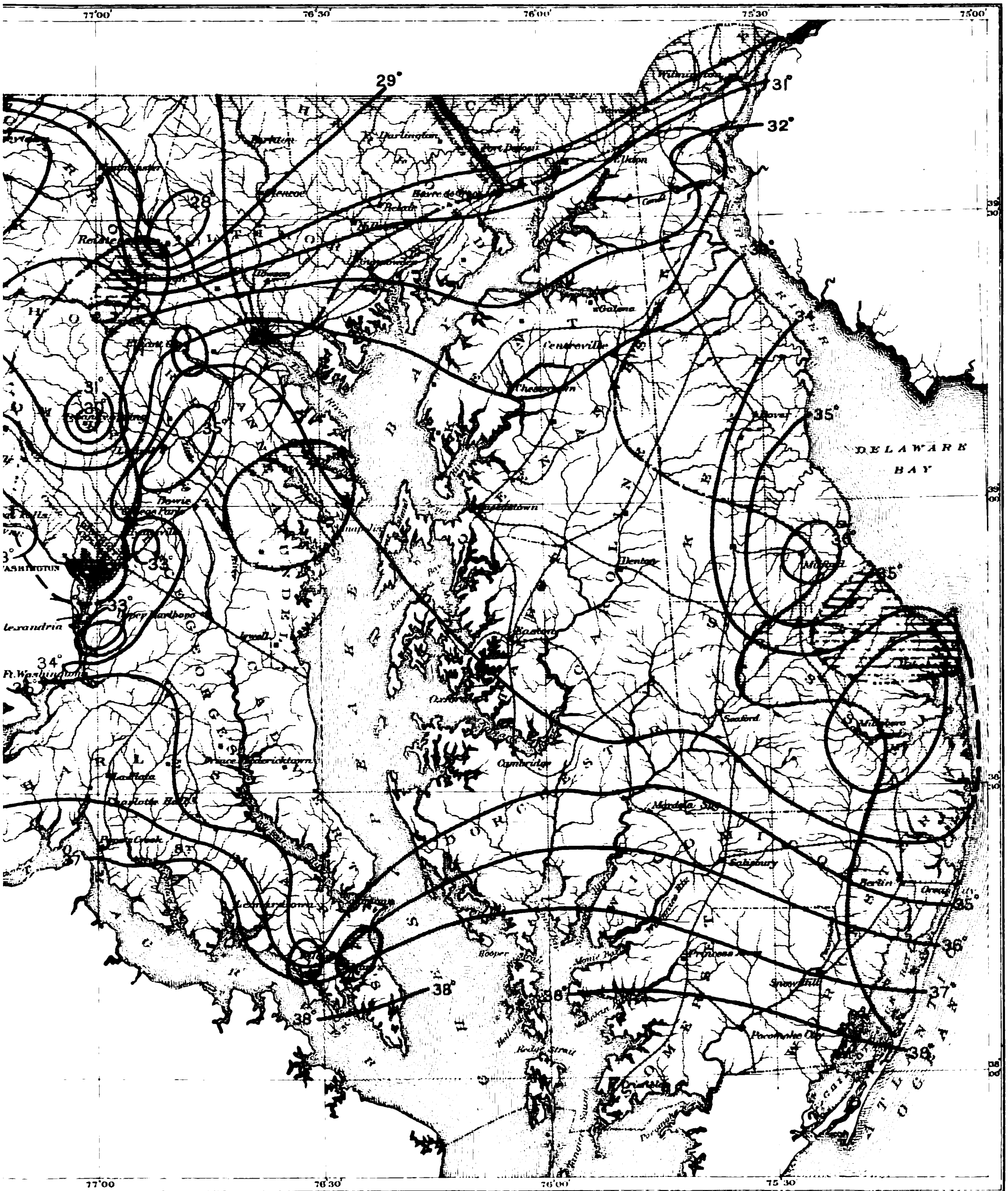
LEGEND

TEMPERATURE IN DEGREES FAHRENHEIT

30° —— 30°

PRECIPITATION IN INCHES

1-2 2-3 3-4 4-5 5-6 6-7



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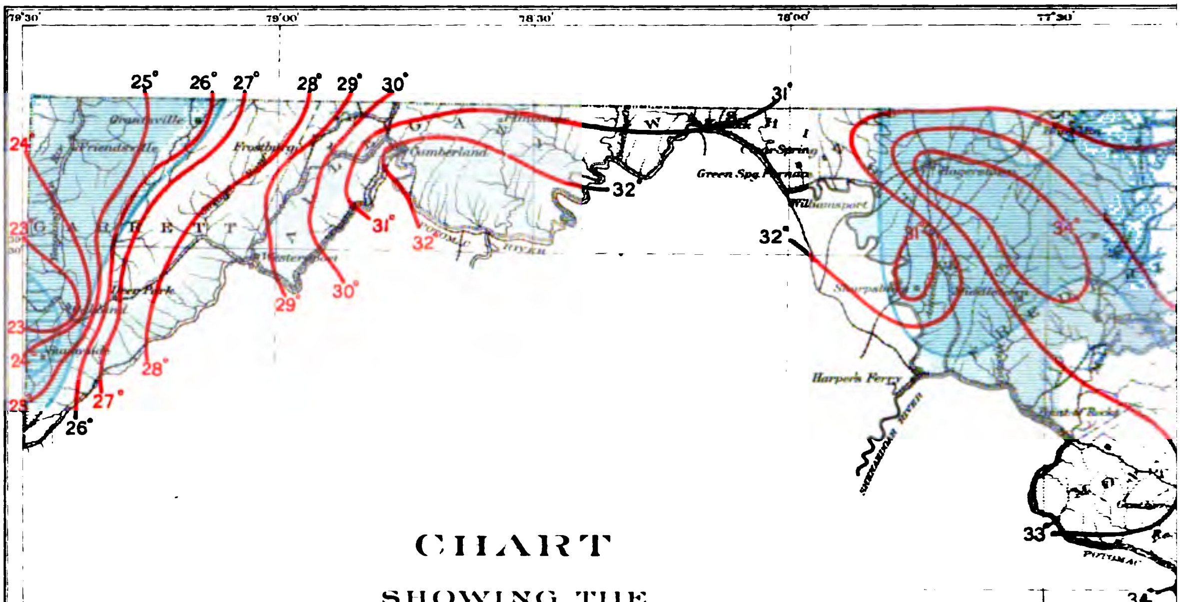
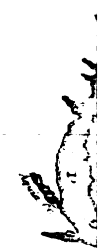




CHART

SHOWING THE

NORMAL TEMPERATURE AND PRECIPITATION

FOR

MARYLAND

INCLUDING

DELAWARE AND THE DISTRICT OF COLUMBIA

FEBRUARY

SCALE

1:1,250,000. 20 Miles = 1 Inch

0 5 10 20 40 60

MARYLAND STATE WEATHER SERVICE

WM. B. CLARK, DIRECTOR

F. J. WALZ, METEOROLOGIST

1899

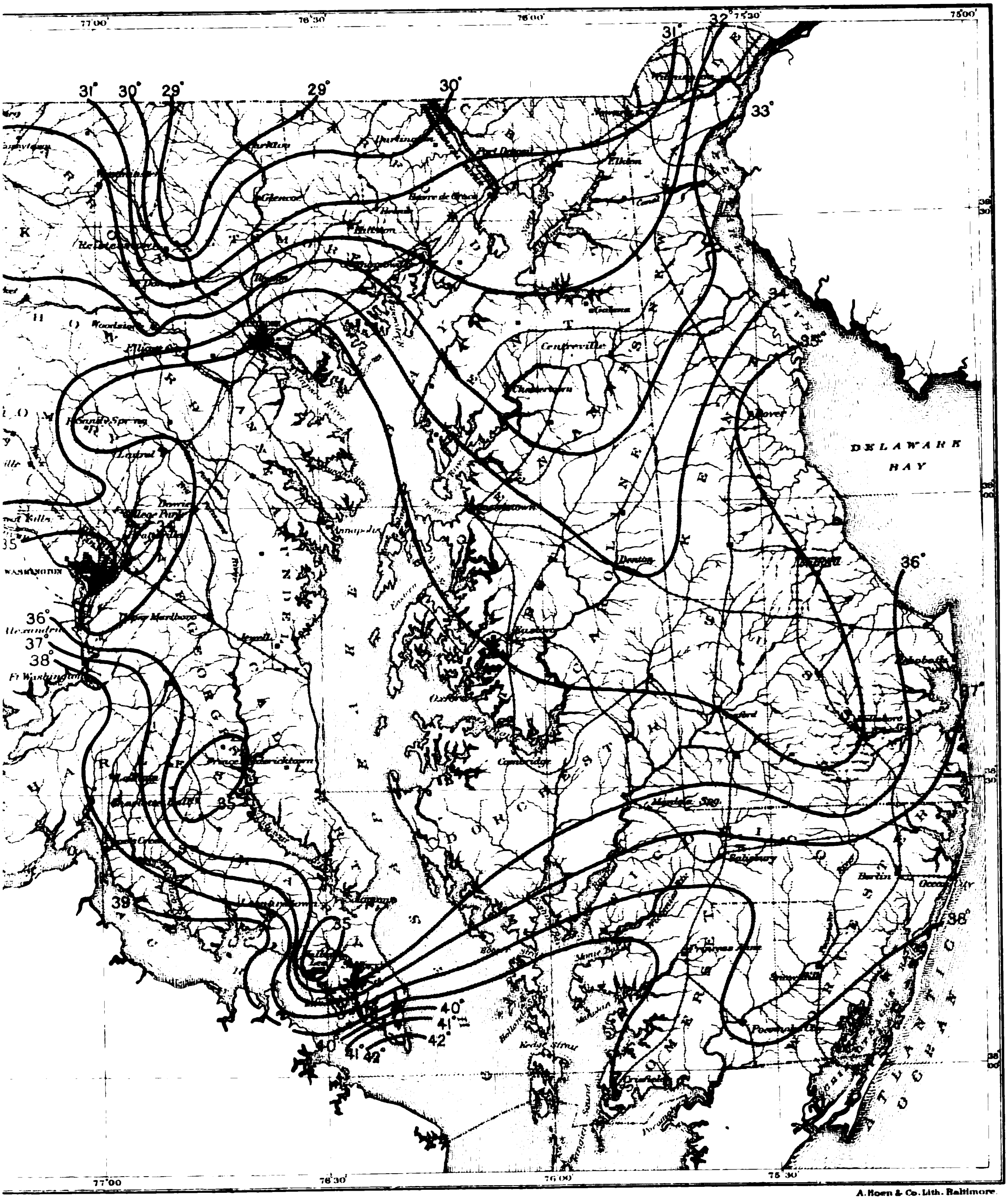
LEGEND

TEMPERATURE IN DEGREES FAHRENHEIT

30° 30°

PRECIPITATION IN INCHES

1-2 2-3 3-4 4-5



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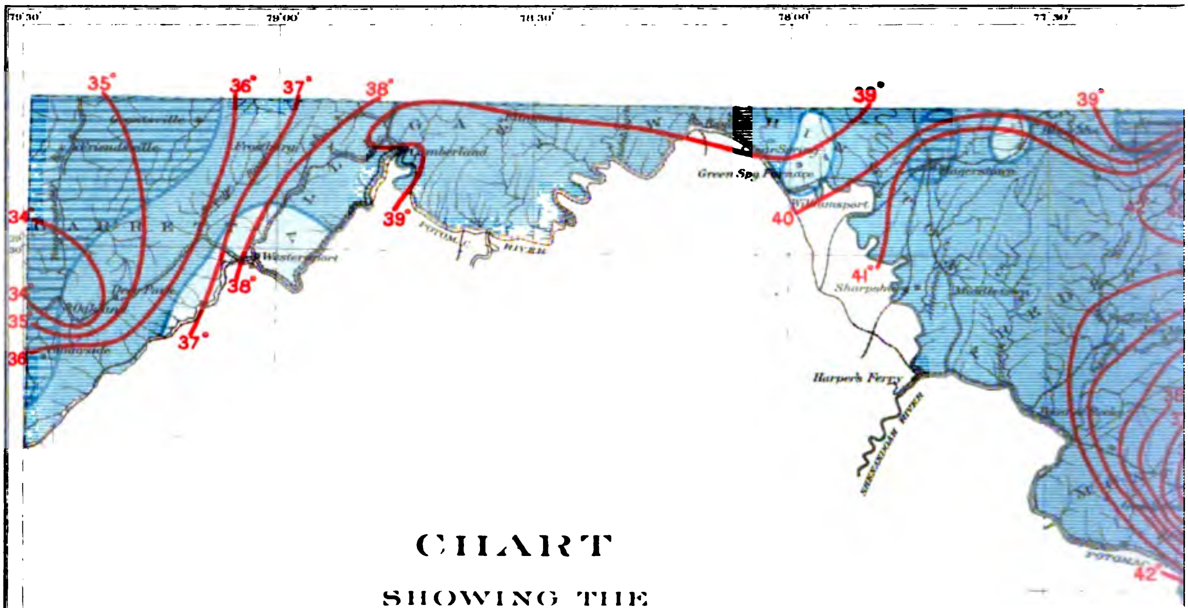


CHART
SHOWING THE
NORMAL TEMPERATURE AND PRECIPITATION
FOR
MARYLAND
INCLUDING
DELAWARE AND THE DISTRICT OF COLUMBIA

MARCH

SCALE
1:1,250,000. 20 Miles = 1 Inch

0 5 10 20 40 60

MARYLAND STATE WEATHER SERVICE

WM. B. CLARK, DIRECTOR

F. J. WALZ, METEOROLOGIST

1899

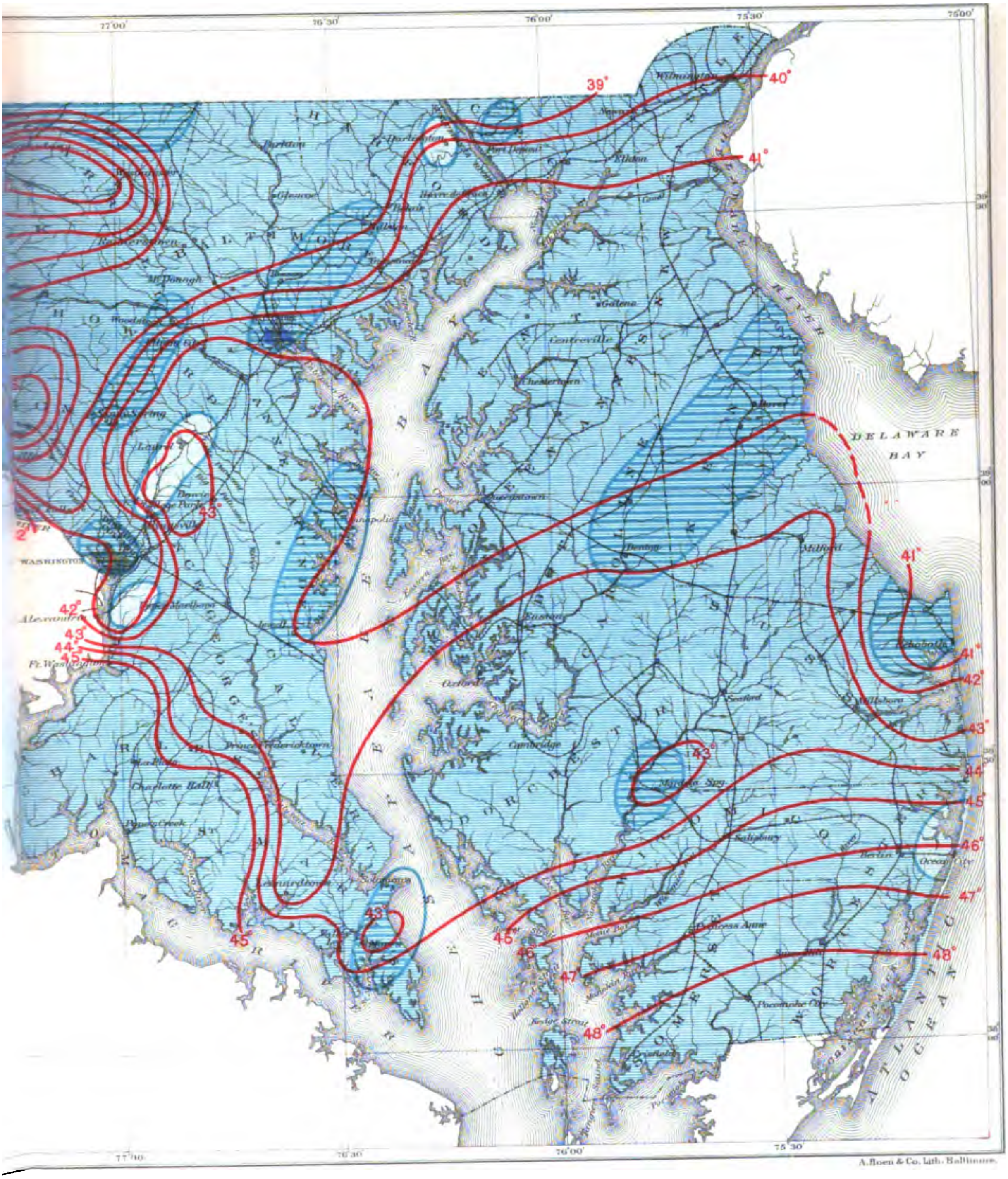
LEGEND

TEMPERATURE IN DEGREES FAHRENHEIT

40° —— 40°

PRECIPITATION IN INCHES

2-3 3-4 4-5



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MARYLAND STATE WEATHER SERVICE

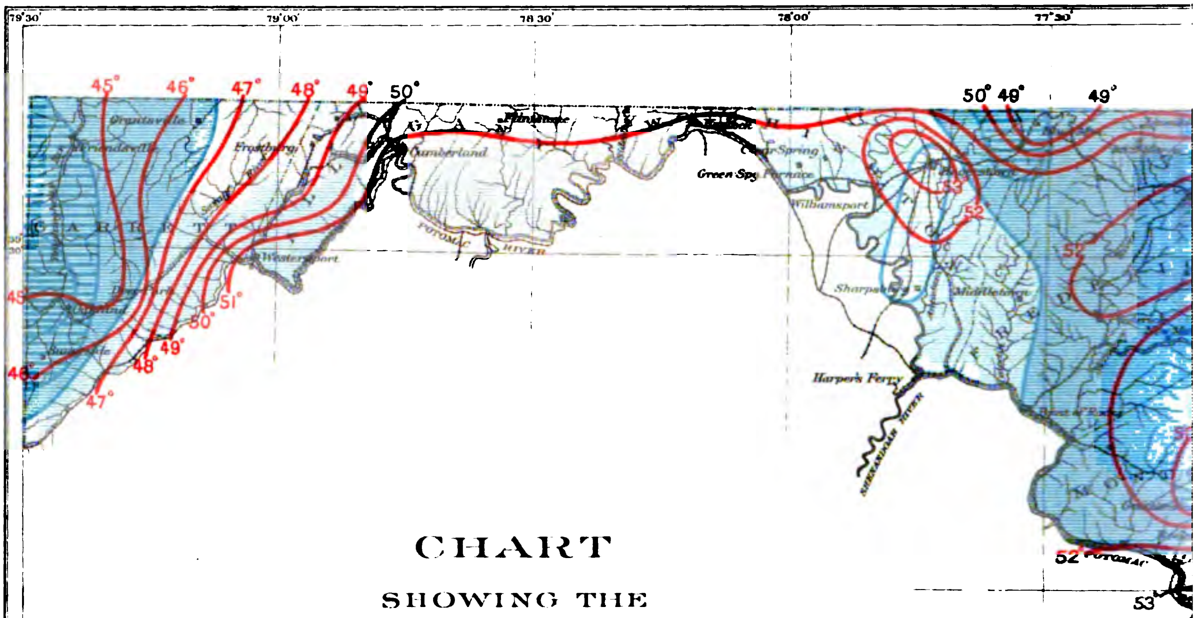


CHART
SHOWING THE
NORMAL TEMPERATURE AND PRECIPITATION
FOR
MARYLAND
INCLUDING
DELAWARE AND THE DISTRICT OF COLUMBIA

APRIL

SCALE

1:1,250,000. 20 Miles = 1 Inch

0 5 10 20 40 60

MARYLAND STATE WEATHER SERVICE

WM. B. CLARK, DIRECTOR

F. J. WALZ, METEOROLOGIST

1899

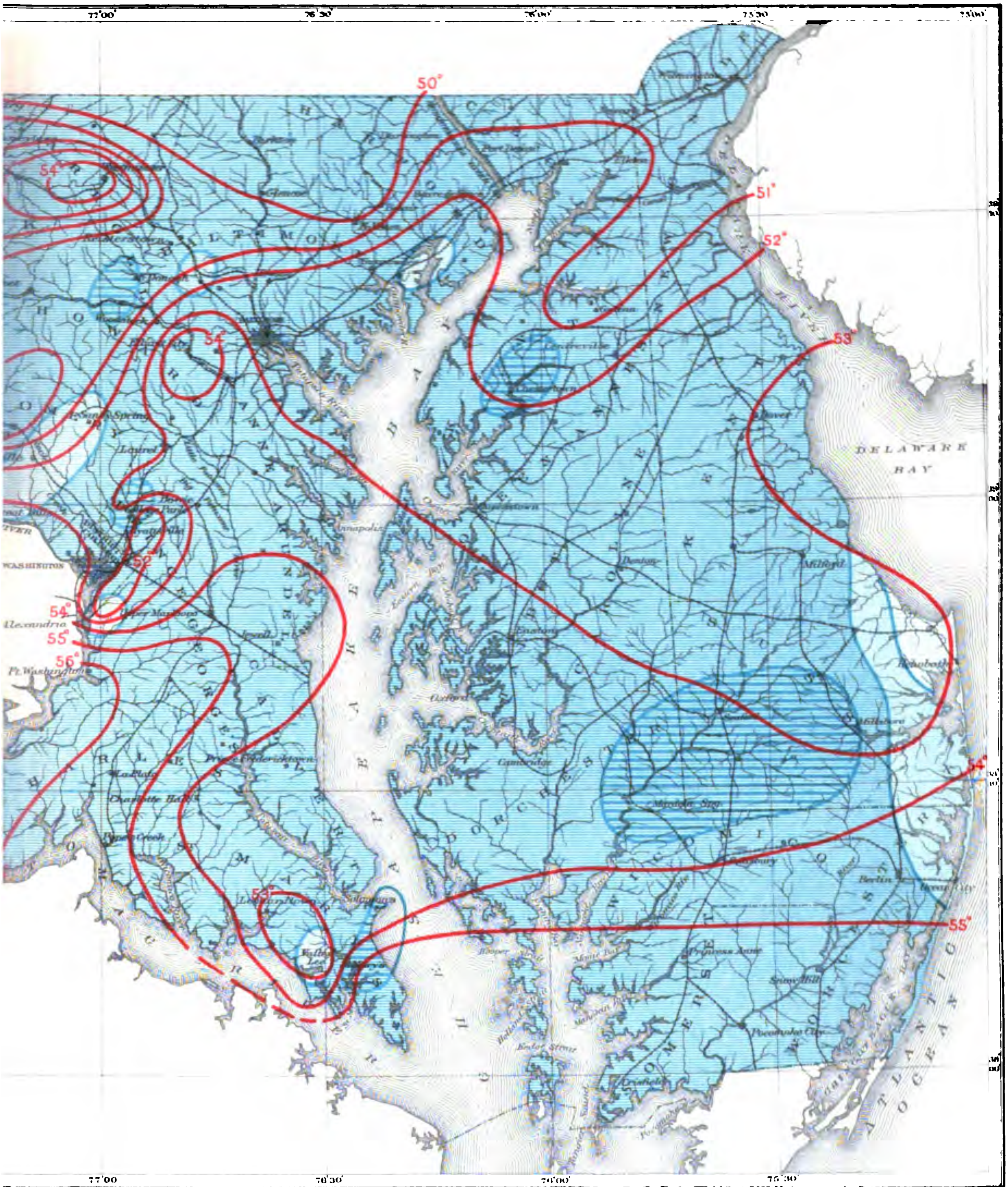
LEGEND

TEMPERATURE IN DEGREES FAHRENHEIT

50° 50°

PRECIPITATION IN INCHES

1-2 2-3 3-4 4-5 5-6



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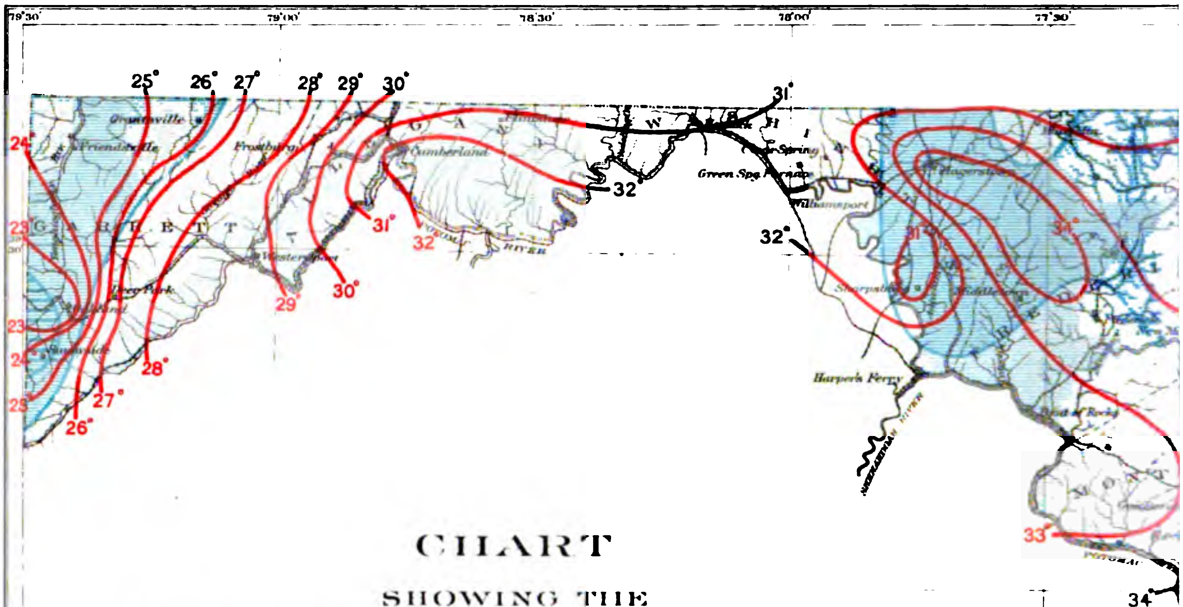


CHART

SHOWING THE

NORMAL TEMPERATURE AND PRECIPITATION

FOR

MARYLAND

INCLUDING

DELAWARE AND THE DISTRICT OF COLUMBIA

FEBRUARY

SCALE

1:1,250,000. 20 Miles = 1 Inch

0 5 10 20 40 60

MARYLAND STATE WEATHER SERVICE

WM. B. CLARK, DIRECTOR

F. J. WALZ, METEOROLOGIST

1899

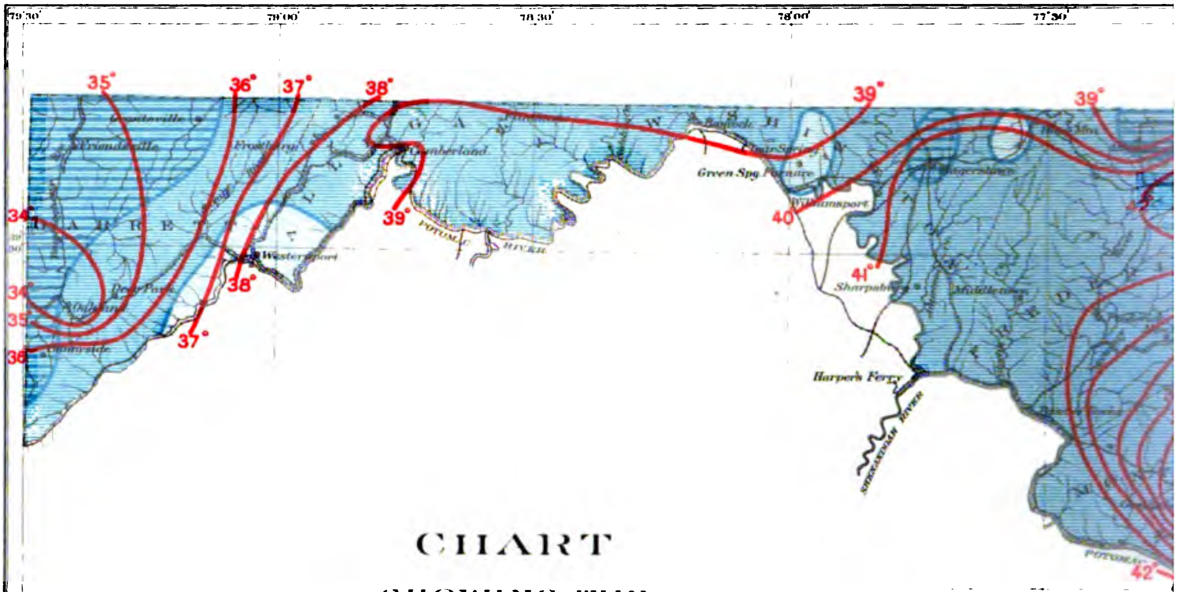
LEGEND

TEMPERATURE IN DEGREES FAHRENHEIT

30° 30°

PRECIPITATION IN INCHES

1-2 2-3 3-4 4-5



CHART

SHOWING THE

NORMAL TEMPERATURE AND PRECIPITATION

FOR

MARYLAND

INCLUDING

DELAWARE AND THE DISTRICT OF COLUMBIA

MARCH

SCALE

1 : 1,250,000. 20 Miles = 1 Inch

0 5 10 20 40 60

MARYLAND STATE WEATHER SERVICE

WM. B. CLARK, DIRECTOR

F. J. WALZ, METEOROLOGIST

1899

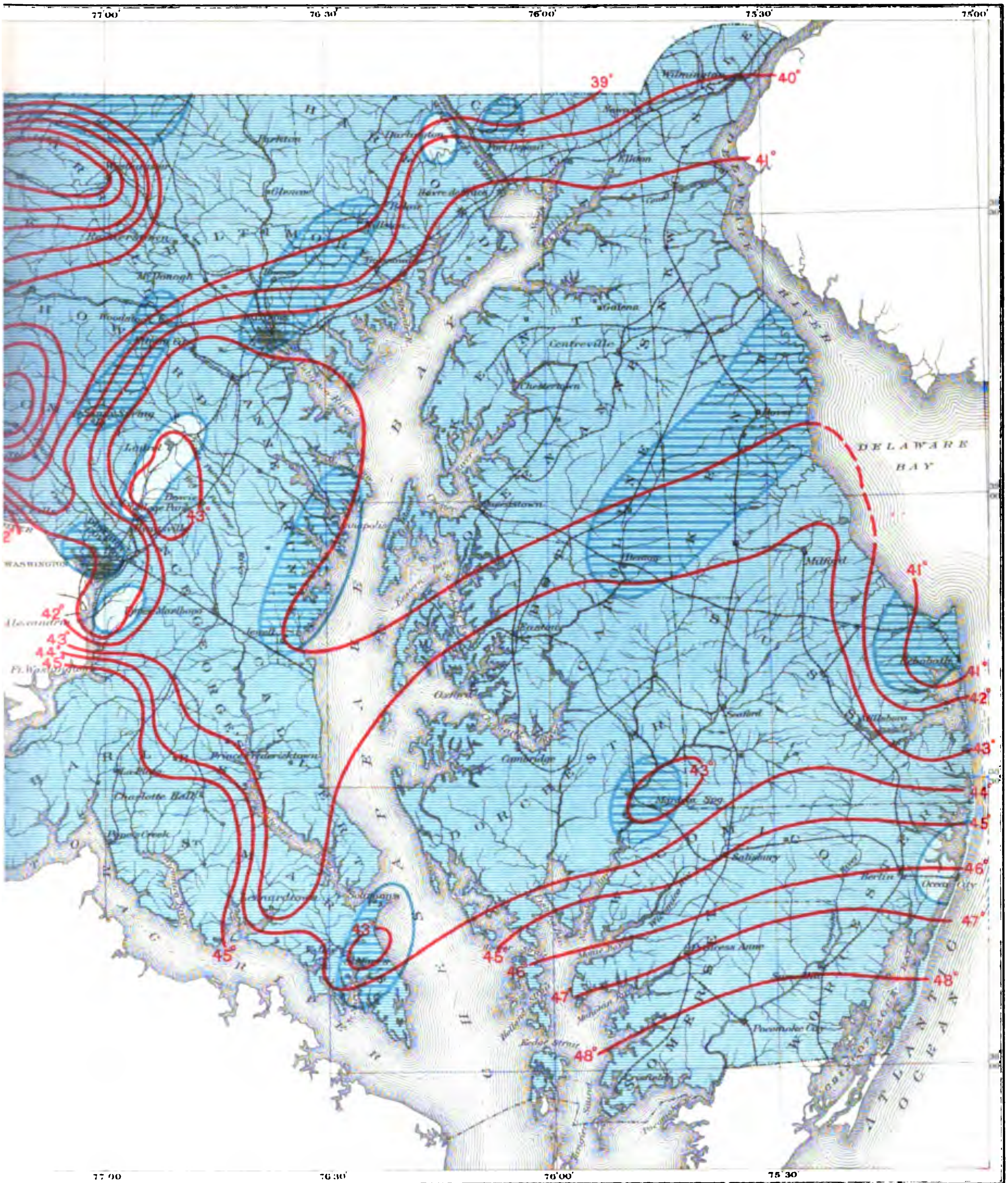
LEGEND

TEMPERATURE IN DEGREES FAHRENHEIT

40° — 40°

PRECIPITATION IN INCHES

2-3 3-4 4-5



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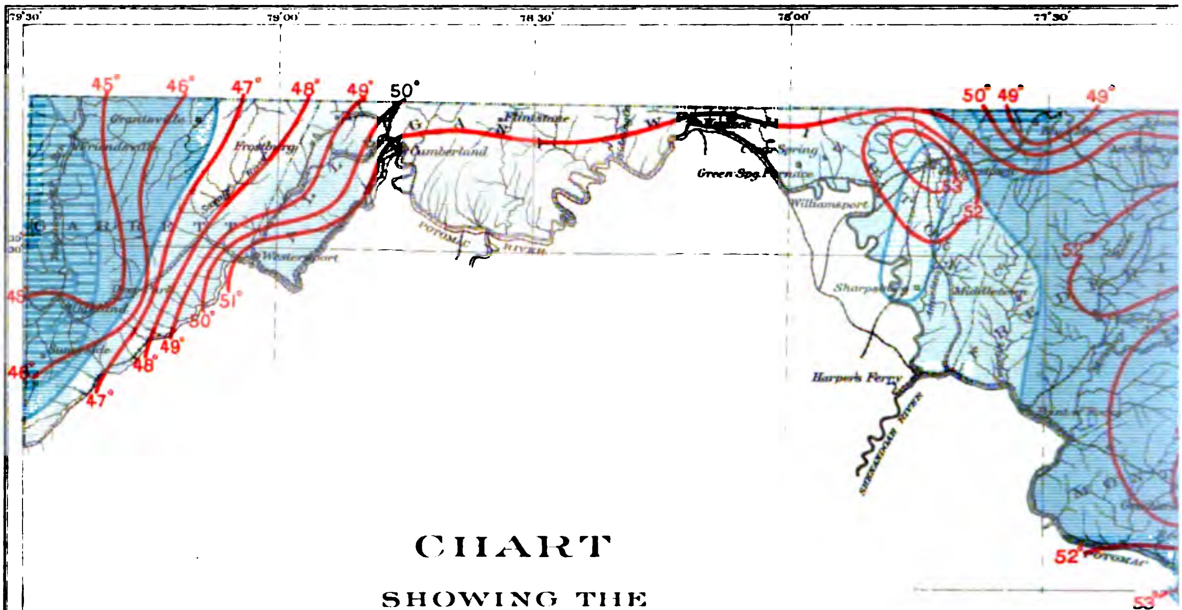


CHART

SHOWING THE

NORMAL TEMPERATURE AND PRECIPITATION

FOR

MARYLAND

INCLUDING

DELAWARE AND THE DISTRICT OF COLUMBIA

APRIL

SCALE

1:1,250,000. 20 Miles = 1 Inch

0 5 10 20 40 60

MARYLAND STATE WEATHER SERVICE

WM. B. CLARK, DIRECTOR

F. J. WALZ, METEOROLOGIST

1899

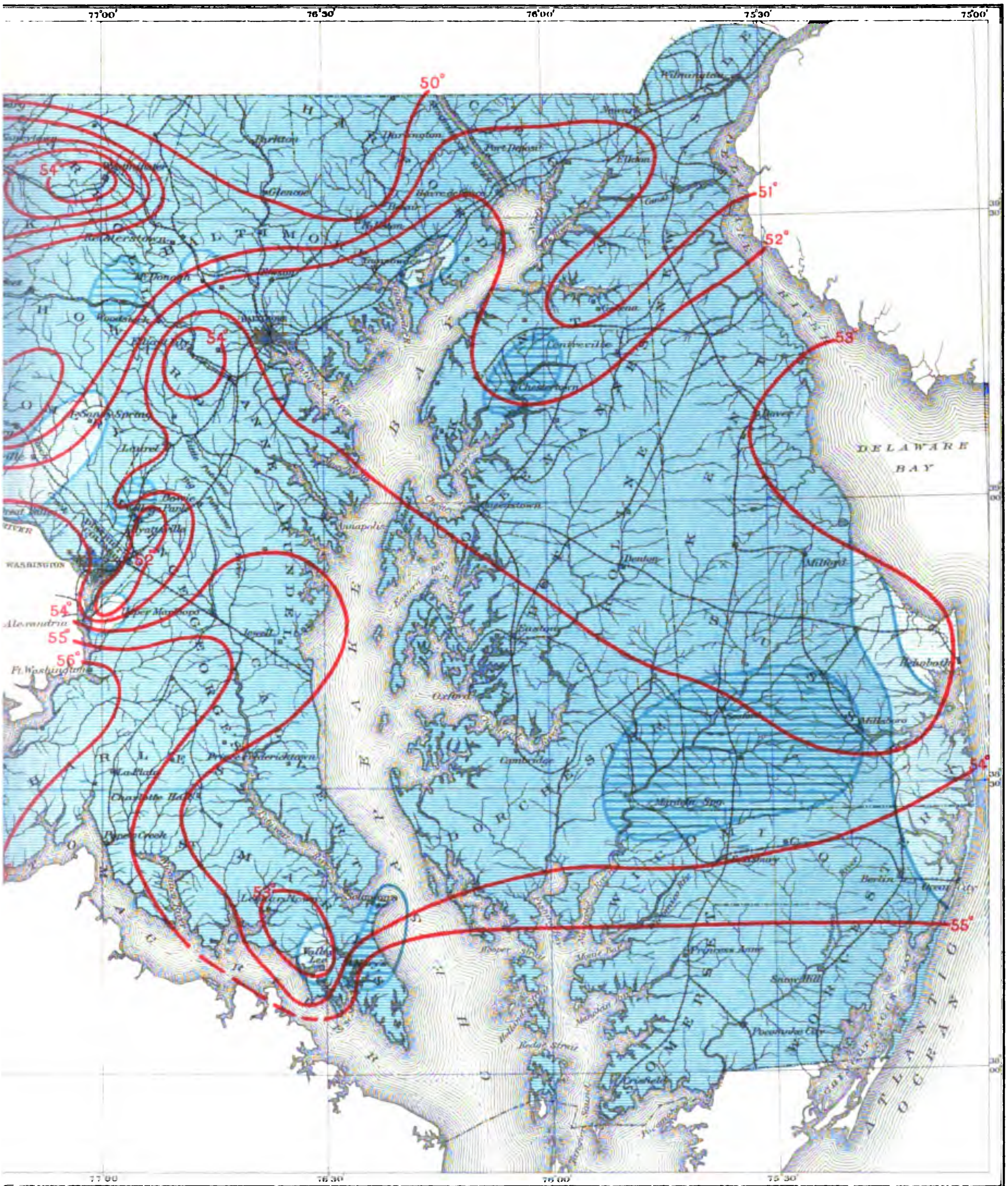
LEGEND

TEMPERATURE IN DEGREES FAHRENHEIT

50° —— 50°

PRECIPITATION IN INCHES

1-2 2-3 3-4 4-5 5-6



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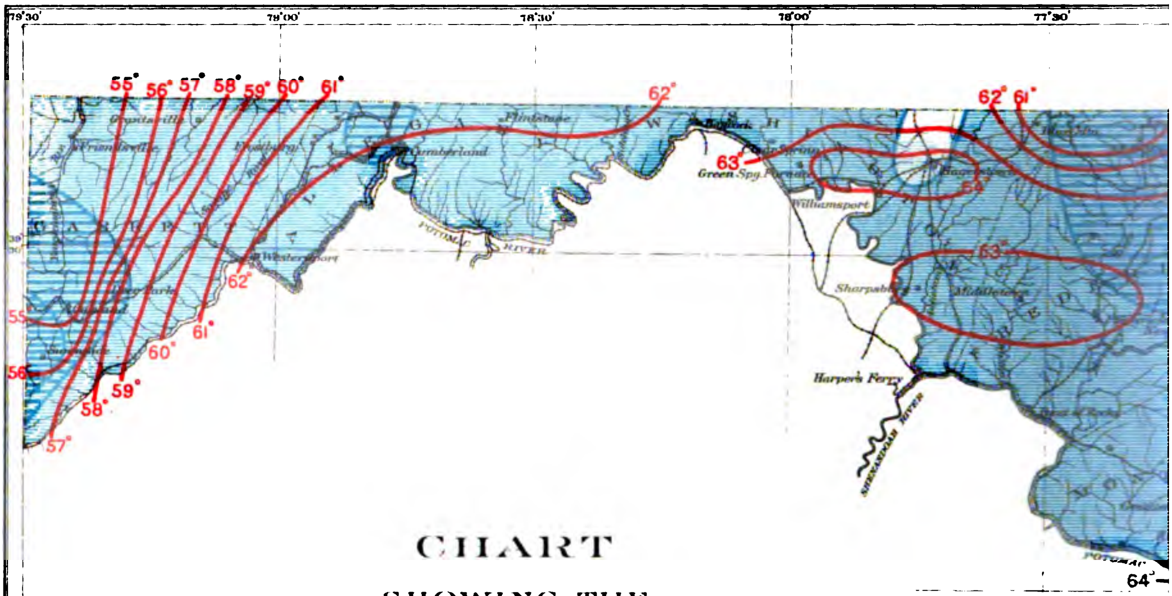


CHART

SHOWING THE

NORMAL TEMPERATURE AND PRECIPITATION

FOR

MARYLAND

INCLUDING

DELAWARE AND THE DISTRICT OF COLUMBIA

MAY

SCALE

1:1,250,000. 20 Miles = 1 Inch

0 5 10 20 40 60

MARYLAND STATE WEATHER SERVICE

WM. B. CLARK, DIRECTOR

F. J. WALZ, METEOROLOGIST

1899

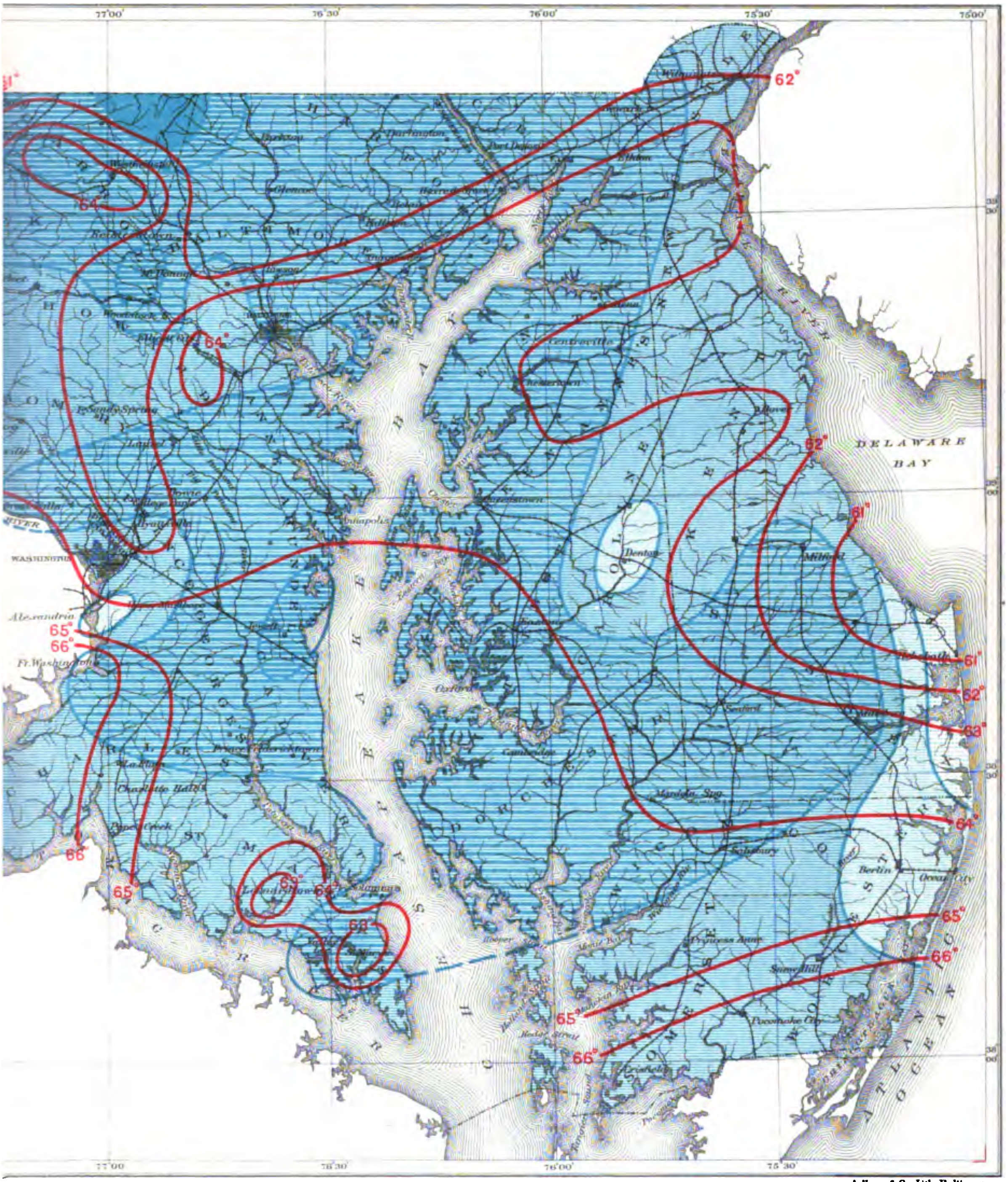
LEGEND

TEMPERATURE IN DEGREES FAHRENHEIT

60° 60°

PRECIPITATION IN INCHES

1-2 2-3 3-4 4-5 5-6 6-7



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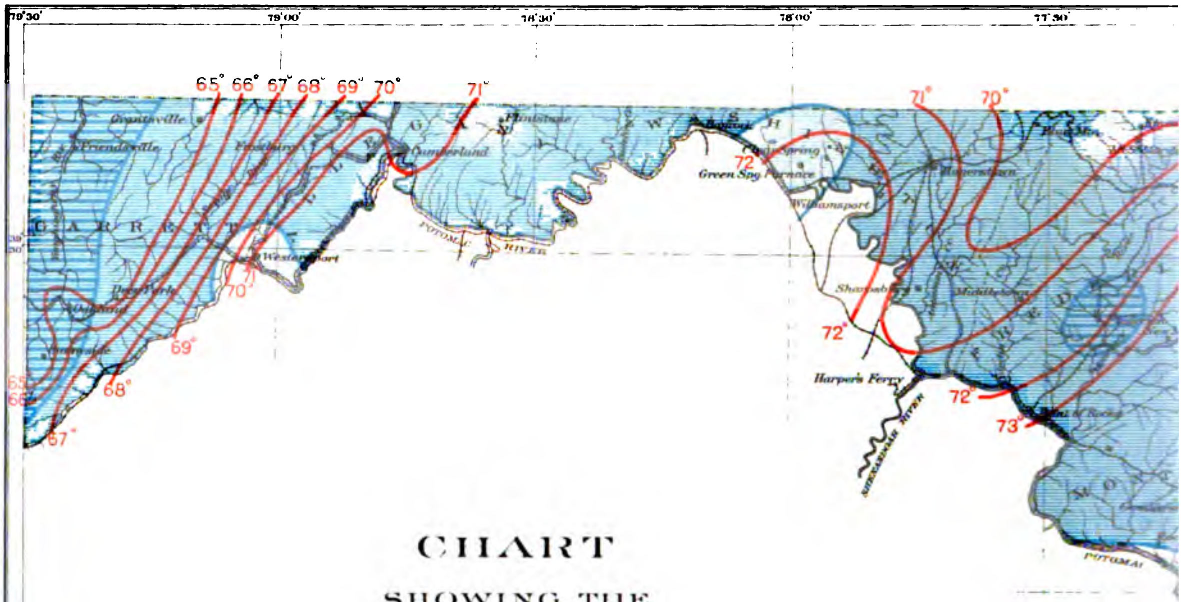


CHART
SHOWING THE
NORMAL TEMPERATURE AND PRECIPITATION
FOR
MARYLAND
INCLUDING
DELAWARE AND THE DISTRICT OF COLUMBIA
JUNE

SCALE
1:1,250,000. 20 Miles = 1 Inch
0 5 10 20 40 60

MARYLAND STATE WEATHER SERVICE

WM. B. CLARK, DIRECTOR

F. J. WALZ, METEOROLOGIST

1899

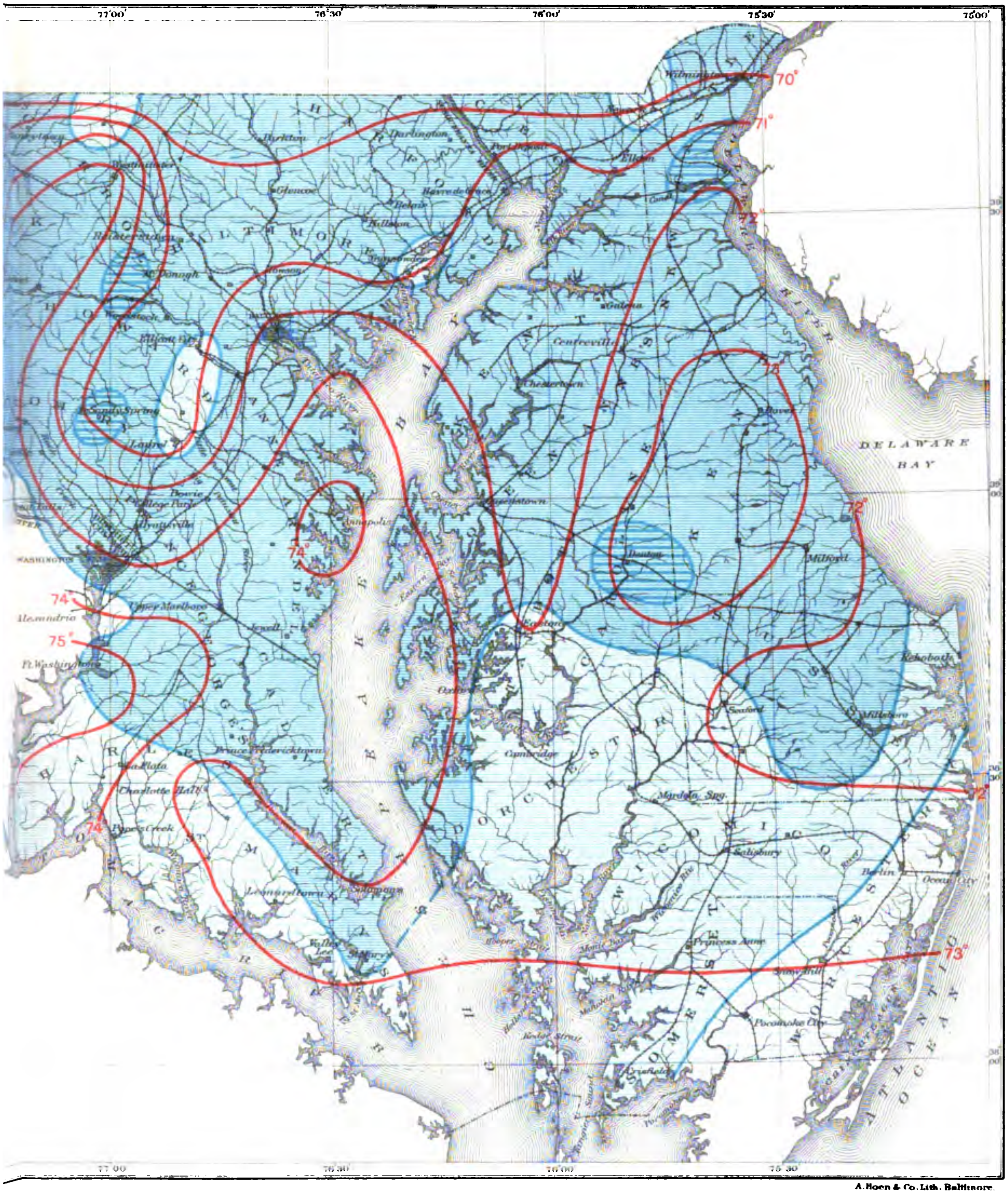
LEGEND

TEMPERATURE IN DEGREES FAHRENHEIT

70° ——— 70°

PRECIPITATION IN INCHES

1-2 2-3 3-4 4-5



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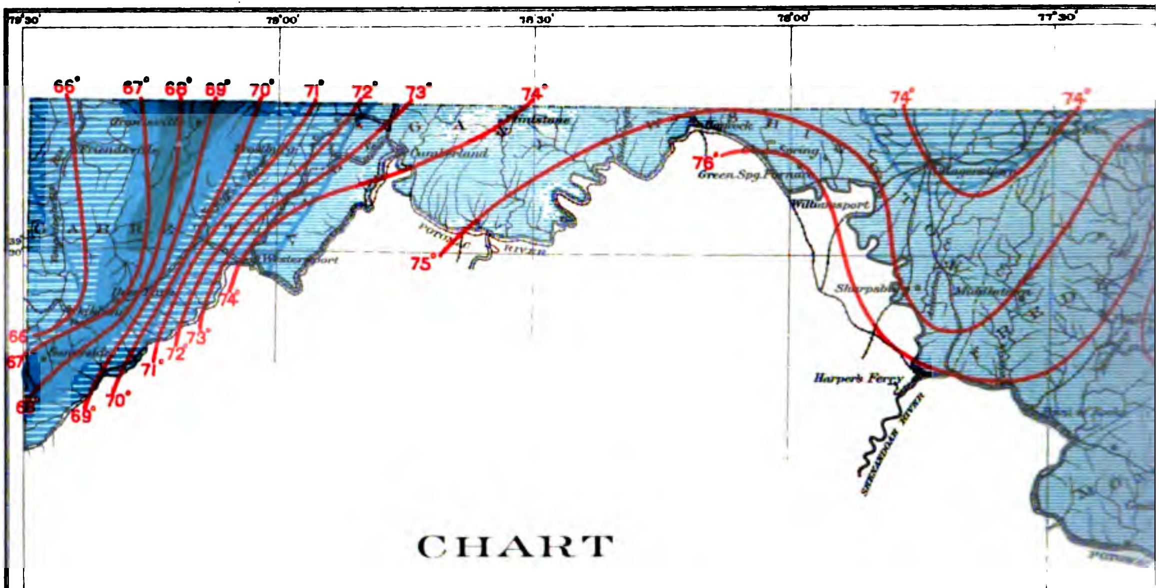
MARYLAND STATE WEATHER SERVICE



CHART

SHOWING THE

NORMAL TEMPERATURE AND PRECIPITATION

FOR

MARYLAND

INCLUDING

DELAWARE AND THE DISTRICT OF COLUMBIA

JULY

SCALE

1:1,250,000. 20 Miles = 1 Inch

0 5 10 20 40 60

MARYLAND STATE WEATHER SERVICE

WM. B. CLARK, DIRECTOR

F. J. WALZ, METEOROLOGIST

1899

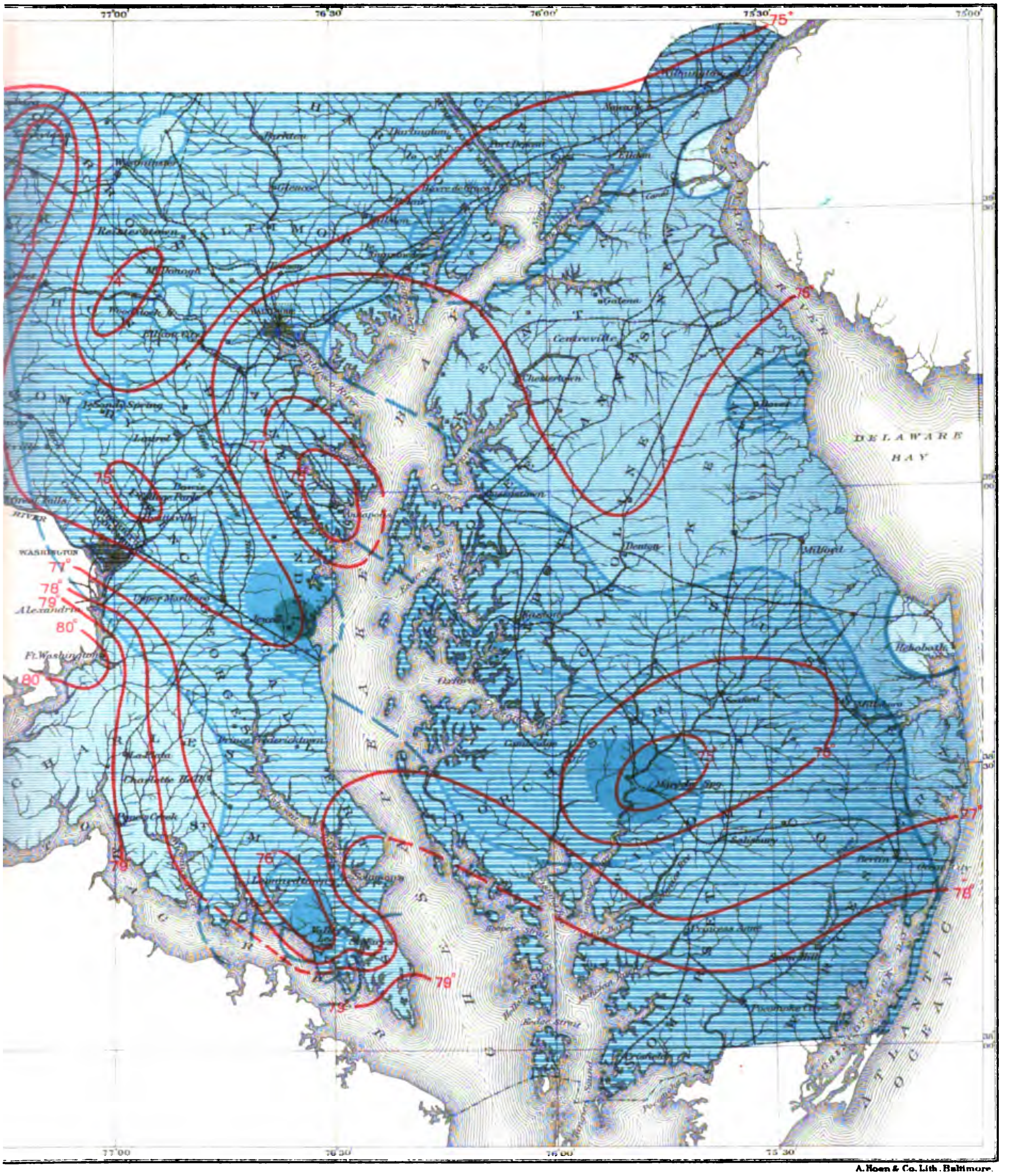
LEGEND

TEMPERATURE IN DEGREES FAHRENHEIT

75° ——— 75°

PRECIPITATION IN INCHES

2-3 3-4 4-5 5-6 6-7 7-8



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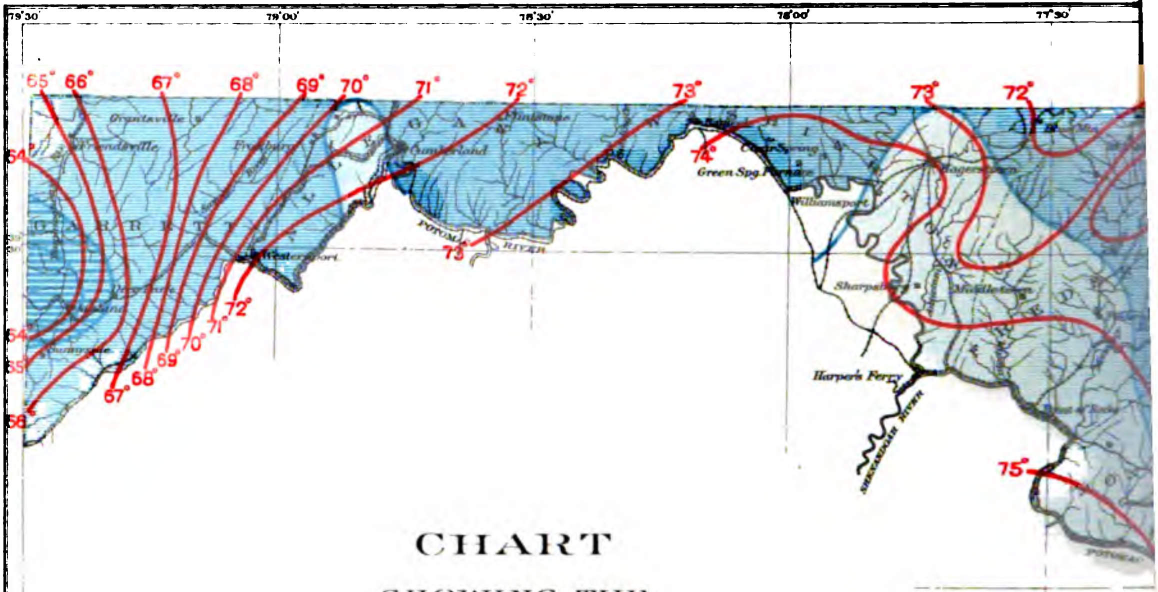


CHART

SHOWING THE

NORMAL TEMPERATURE AND PRECIPITATION

FOR

MARYLAND

INCLUDING

DELAWARE AND THE DISTRICT OF COLUMBIA

AUGUST

SCALE

1:1,250,000. 20 Miles = 1 Inch

0 5 10 20 40 60

MARYLAND STATE WEATHER SERVICE

WM. B. CLARK, DIRECTOR

F. J. WALZ, METEOROLOGIST

1899

LEGEND

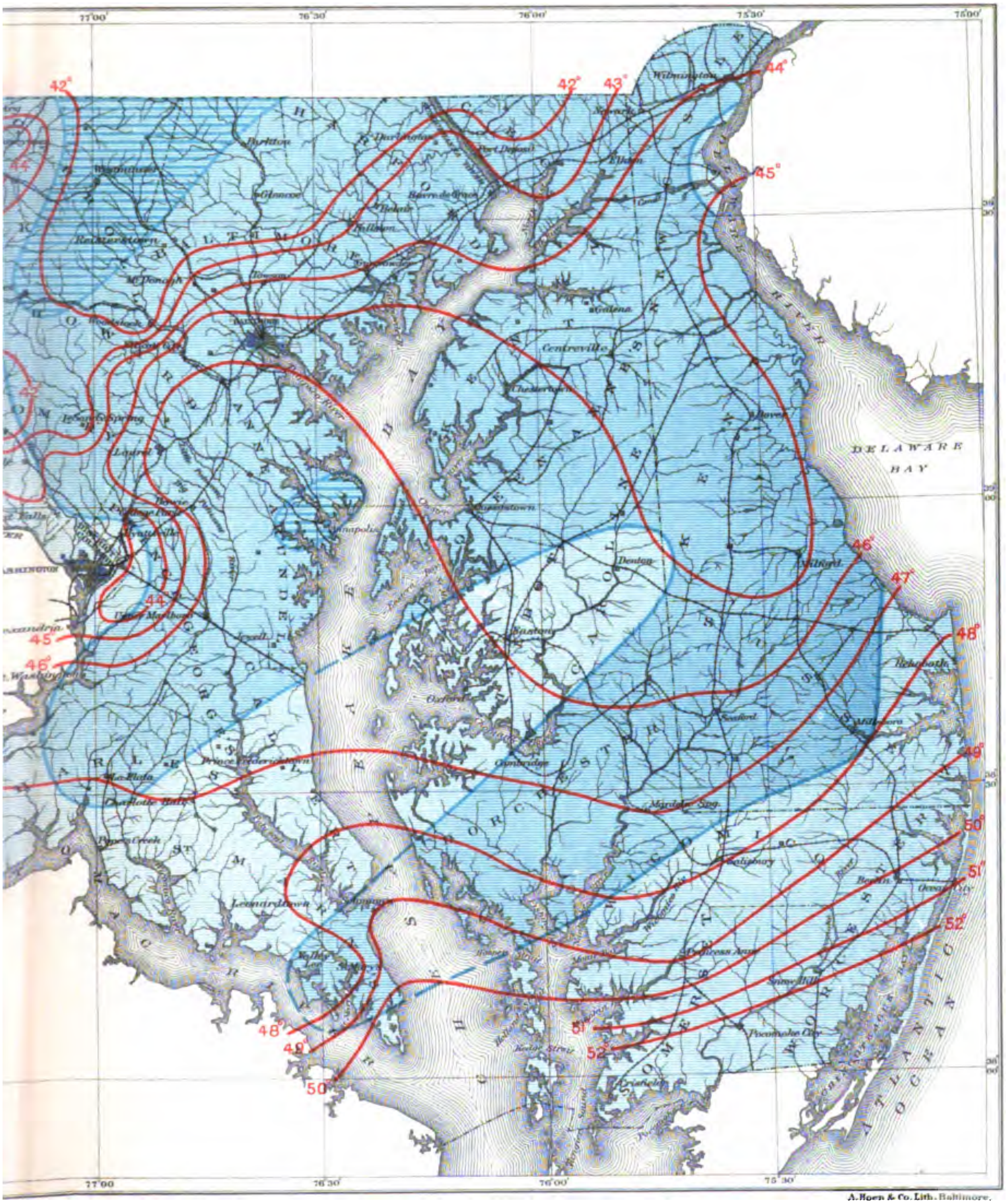
TEMPERATURE IN DEGREES FAHRENHEIT

75° —— 75°

PRECIPITATION IN INCHES

2-3 3-4 4-5 5-6 6-7

VOLUME I. PLATE XLVIII.



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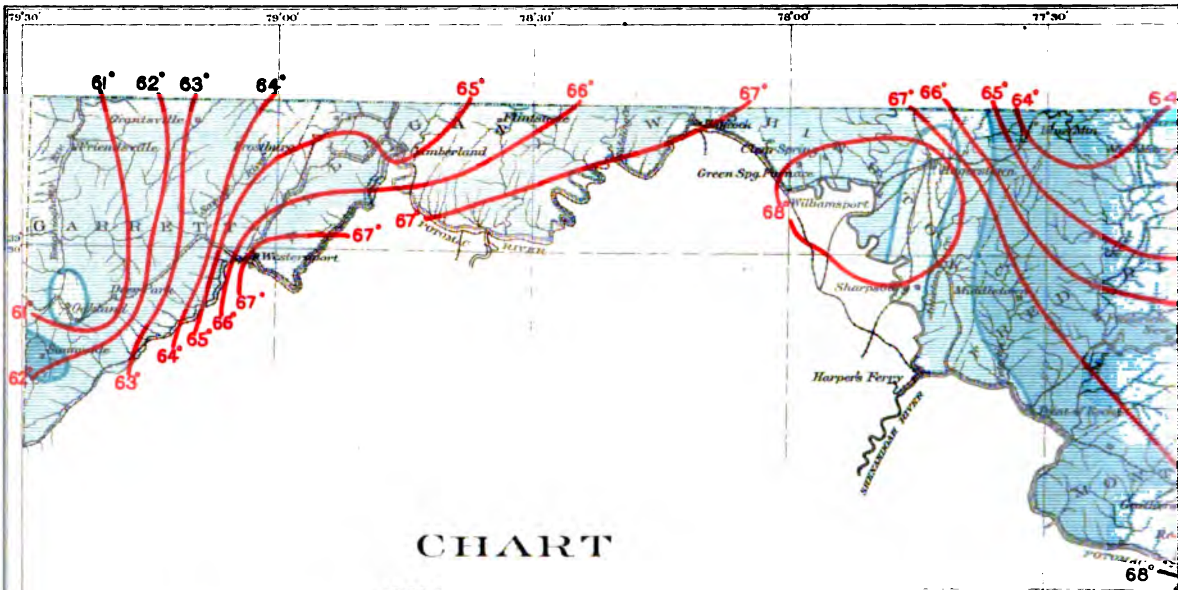


CHART

SHOWING THE

NORMAL TEMPERATURE AND PRECIPITATION

FOR

MARYLAND

INCLUDING

DELAWARE AND THE DISTRICT OF COLUMBIA

SEPTEMBER

SCALE

1:1,250,000. 20 Miles = 1 Inch

0 5 10 20 40 60

MARYLAND STATE WEATHER SERVICE

WM. B. CLARK, DIRECTOR

F. J. WALZ, METEOROLOGIST

1899

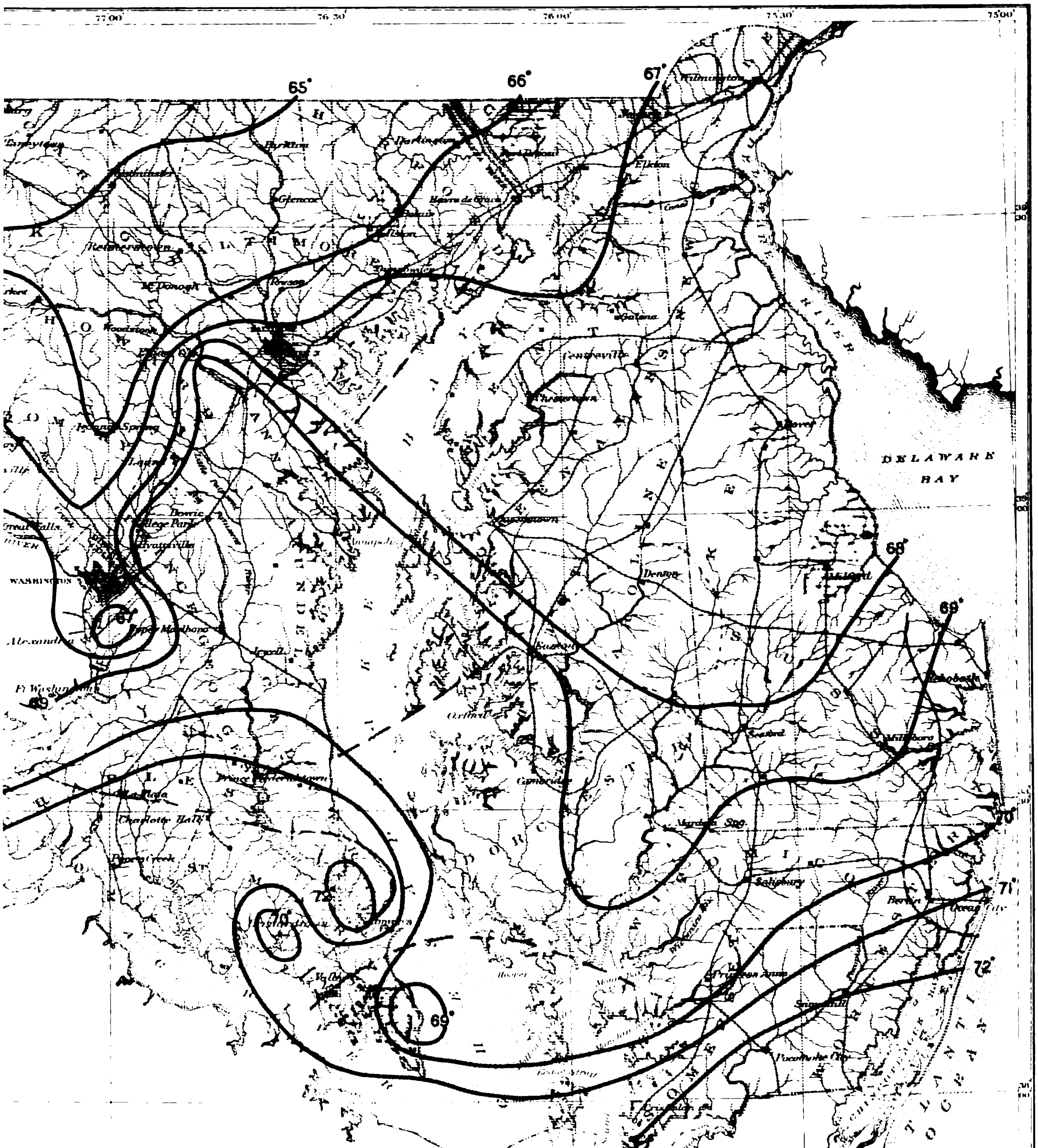
LEGEND

TEMPERATURE IN DEGREES FAHRENHEIT

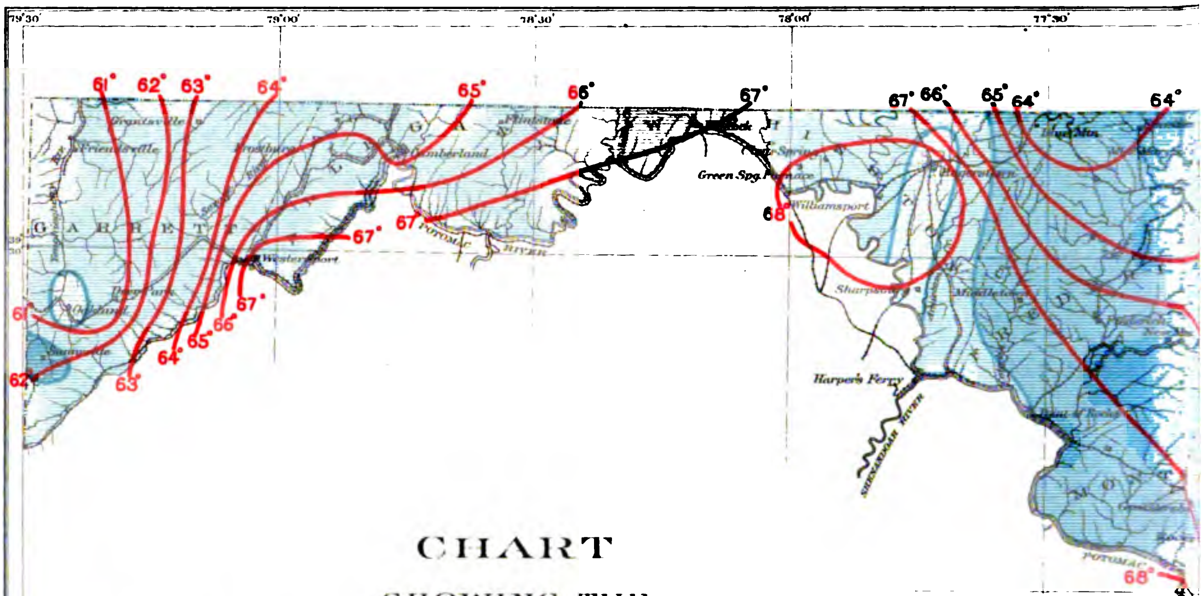
70° 70°

PRECIPITATION IN INCHES

1-2 2-3 3-4 4-5



A.Hoen & Co. Lith. Baltimore.



CHART

SHOWING THE

NORMAL TEMPERATURE AND PRECIPITATION

FOR

MARYLAND

INCLUDING

DELAWARE AND THE DISTRICT OF COLUMBIA

SEPTEMBER

SCALE
1:1,250,000. 20 Miles = 1 Inch

0 5 10 20 40 60

MARYLAND STATE WEATHER SERVICE

WM. B. CLARK, DIRECTOR

F. J. WALZ, METEOROLOGIST

1899

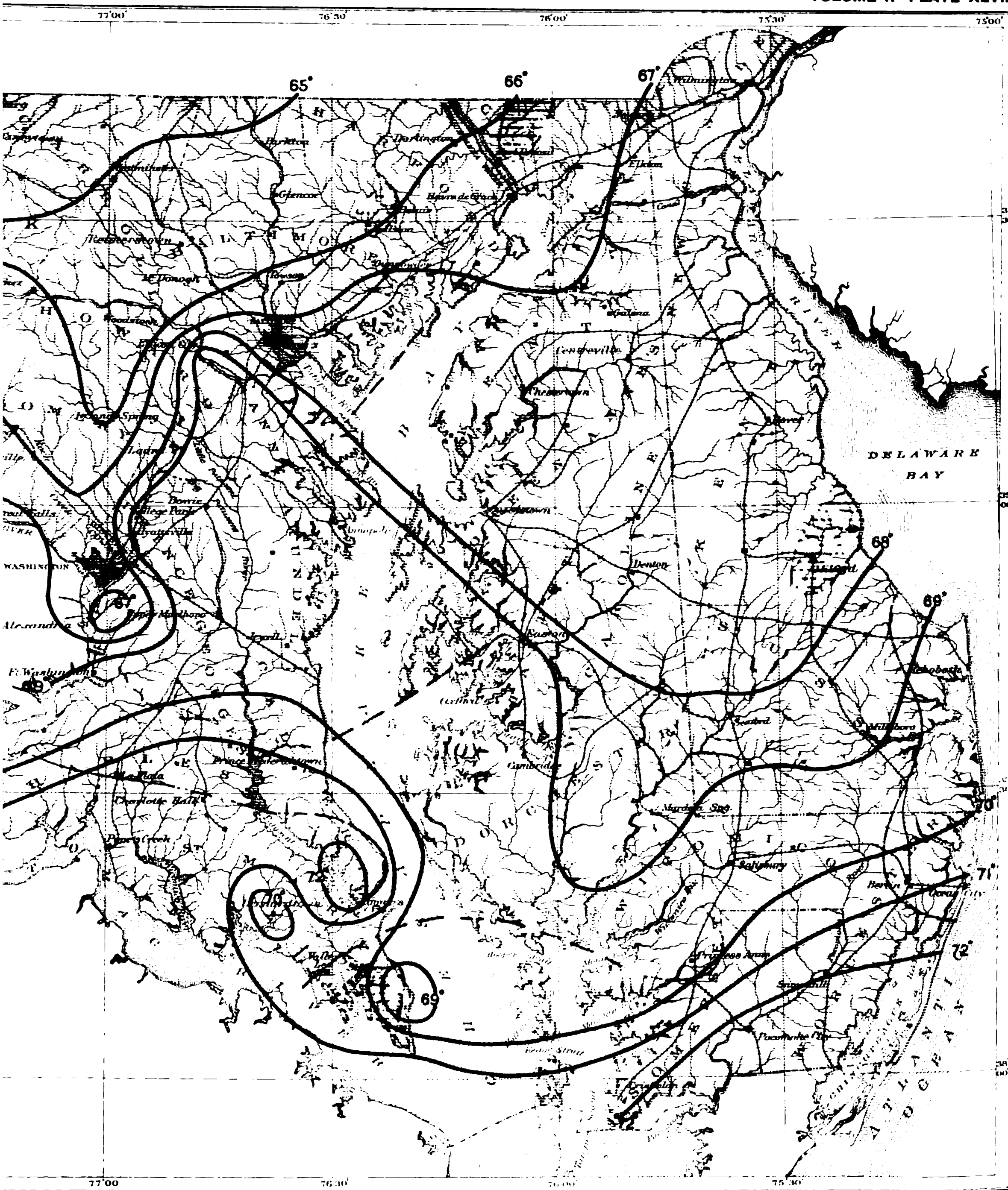
LEGEND

TEMPERATURE IN DEGREES FAHRENHEIT

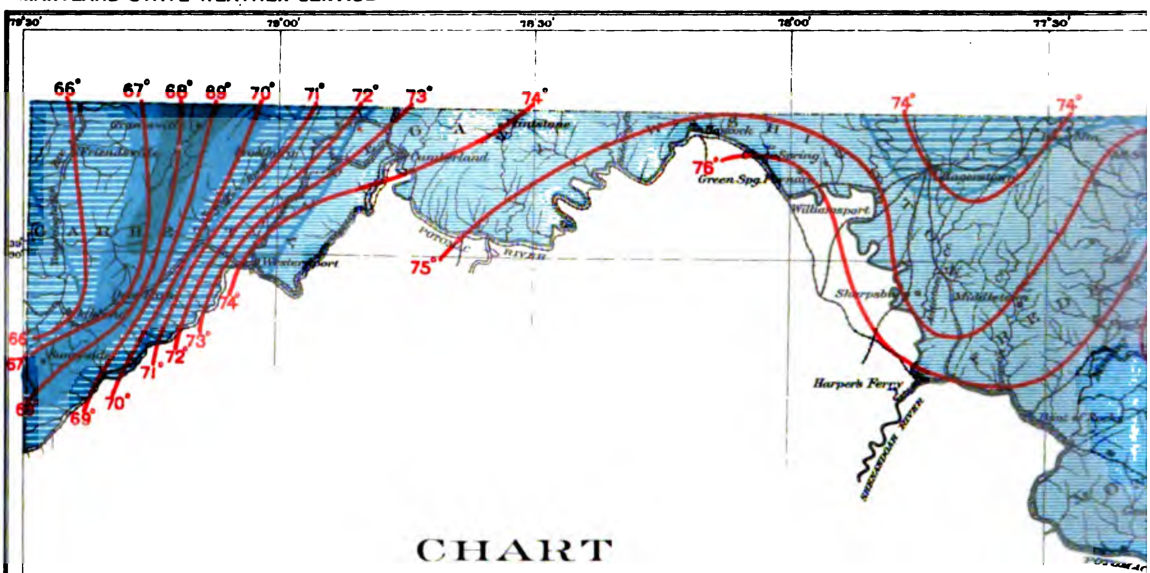
70° —— 70°

PRECIPITATION IN INCHES

1-2	2-3	3-4	4-5



A. Hoen & Co. Lith. Baltimore.



CHART

SHOWING THE

NORMAL TEMPERATURE AND PRECIPITATION

FOR

MARYLAND

INCLUDING

DELAWARE AND THE DISTRICT OF COLUMBIA

JULY

SCALE
1:1,250,000. 20 Miles = 1 Inch

0 5 10 20 40 60

MARYLAND STATE WEATHER SERVICE

WM. B. CLARK, DIRECTOR

F. J. WALZ, METEOROLOGIST

1899

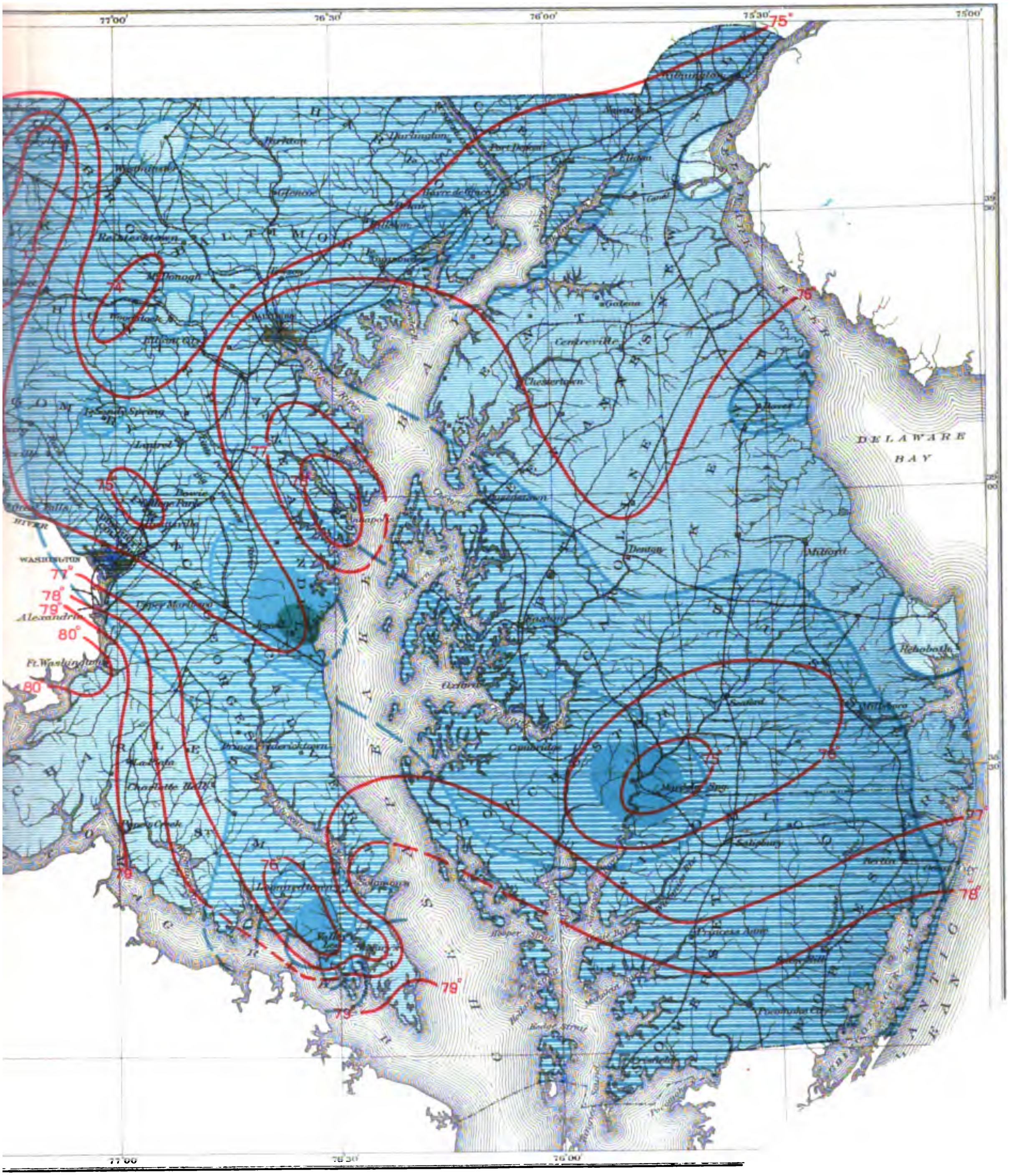
LEGEND

TEMPERATURE IN DEGREES FAHRENHEIT

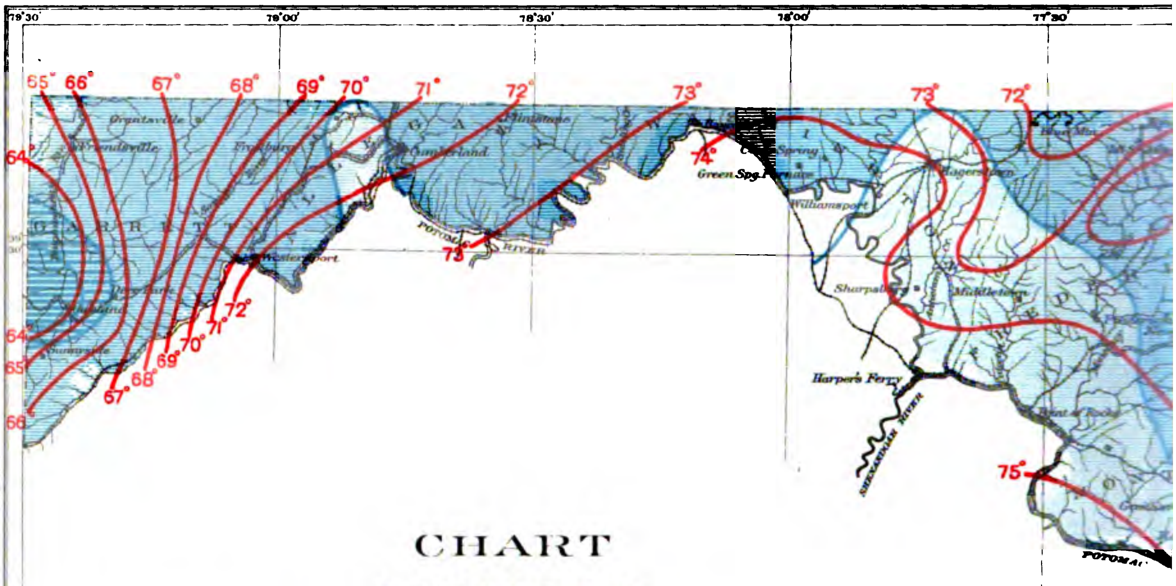
75° 75°

PRECIPITATION IN INCHES

2-3 3-4 4-5 5-6 6-7 7-8


77°00'
76°30'
76°00'
75°30'
75°00'
75°
76°
77°
78°
79°
80°
WASHINGTON
Alexandria
Ft. Washington
DELAWARE
BAY
Chestertown
Centreville
Denton
Milford
Rehoboth
Salisbury
Princess Anne
Cambridge
Oxford
Easton
Elkton
Galena
Dover
Seaford
Laurel

2-3



CHART

SHOWING THE

NORMAL TEMPERATURE AND PRECIPITATION

FOR

MARYLAND

INCLUDING

DELAWARE AND THE DISTRICT OF COLUMBIA

AUGUST

SCALE

1:1,250,000. 20 Miles = 1 Inch

0 5 10 20 40 60

MARYLAND STATE WEATHER SERVICE

WM. B. CLARK, DIRECTOR

F. J. WALZ, METEOROLOGIST

1899

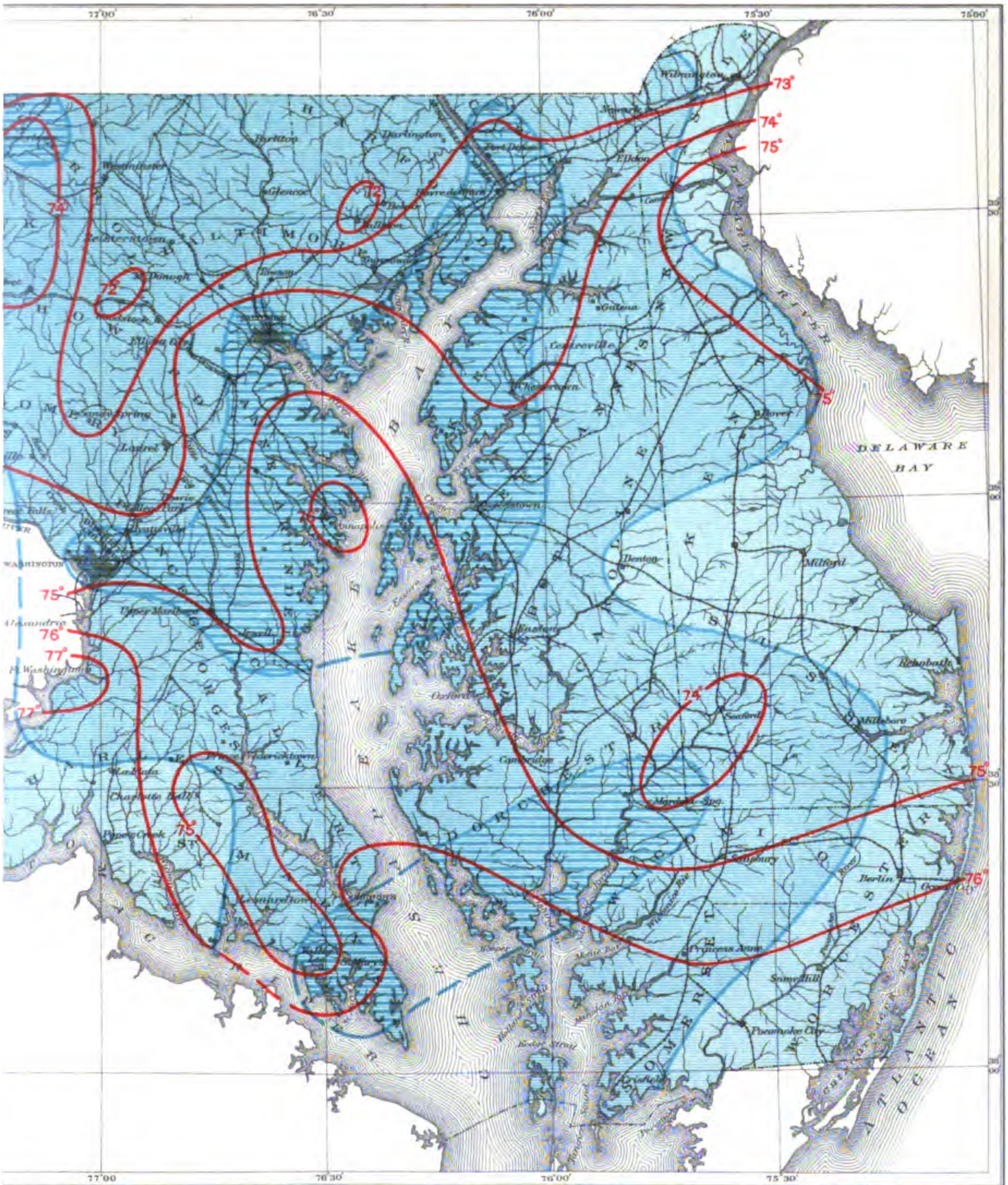
LEGEND

TEMPERATURE IN DEGREES FAHRENHEIT

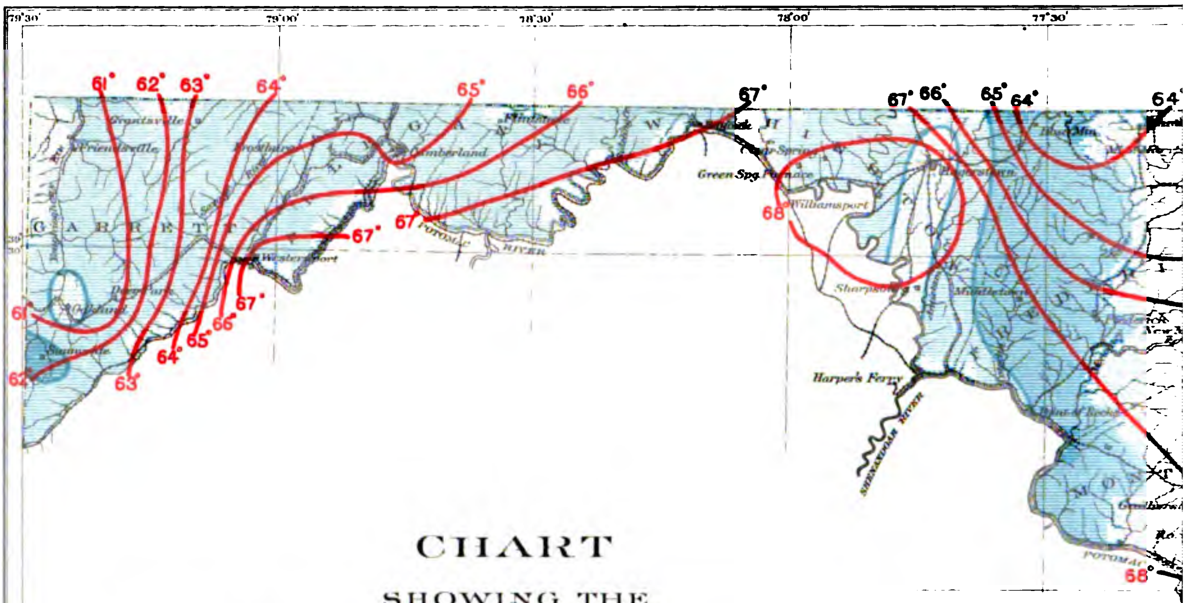
75° 75°

PRECIPITATION IN INCHES

2-3 3-4 4-5 5-6 6-7



A. Hoen & Co. Lith. Baltimore.



CHART

SHOWING THE

NORMAL TEMPERATURE AND PRECIPITATION

FOR

MARYLAND

INCLUDING

DELAWARE AND THE DISTRICT OF COLUMBIA

SEPTEMBER

SCALE

1:1,250,000. 20 Miles = 1 Inch

0 5 10 20 40 60

MARYLAND STATE WEATHER SERVICE

WM. B. CLARK, DIRECTOR

F. J. WALZ, METEOROLOGIST

1899

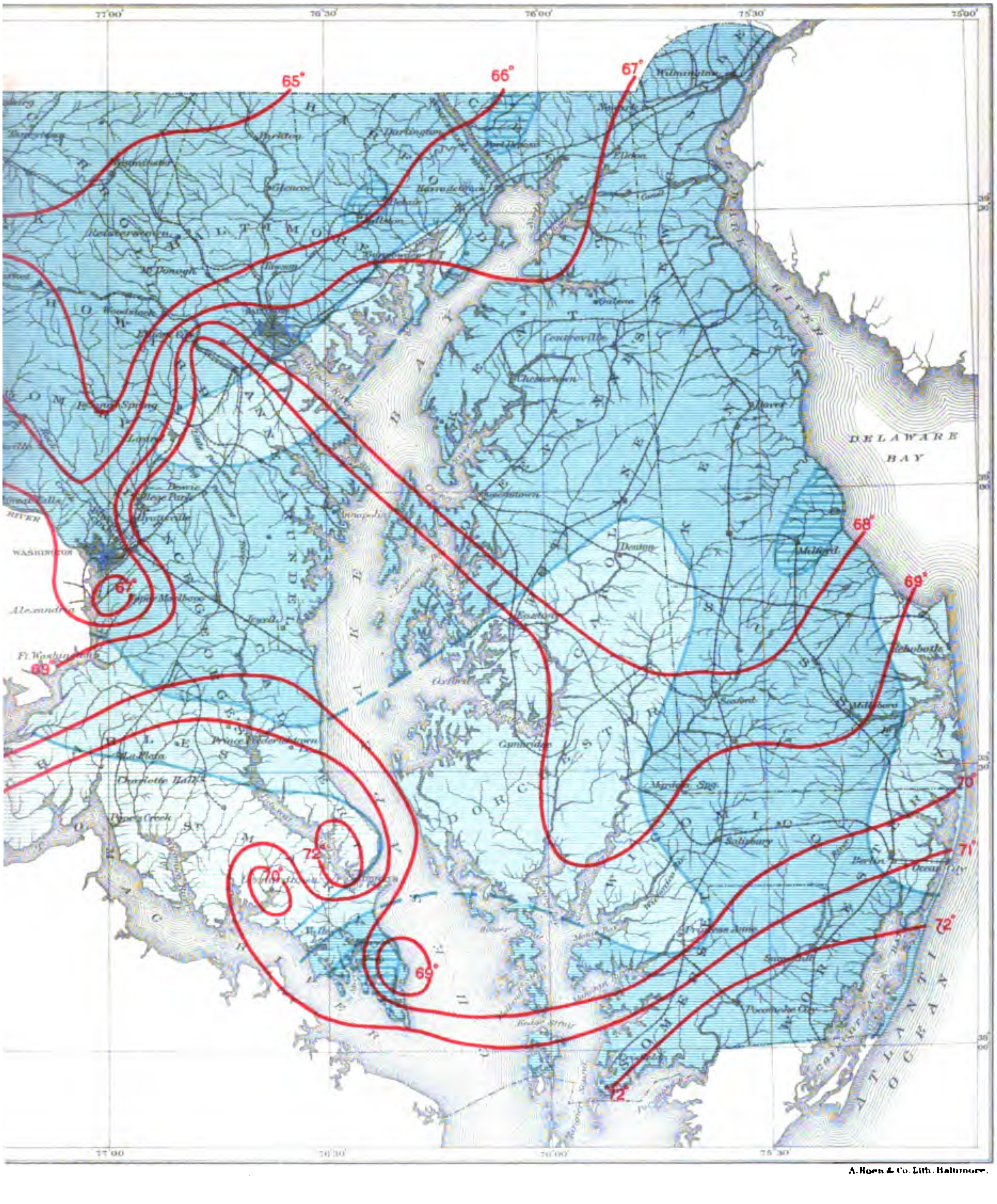
LEGEND

TEMPERATURE IN DEGREES FAHRENHEIT

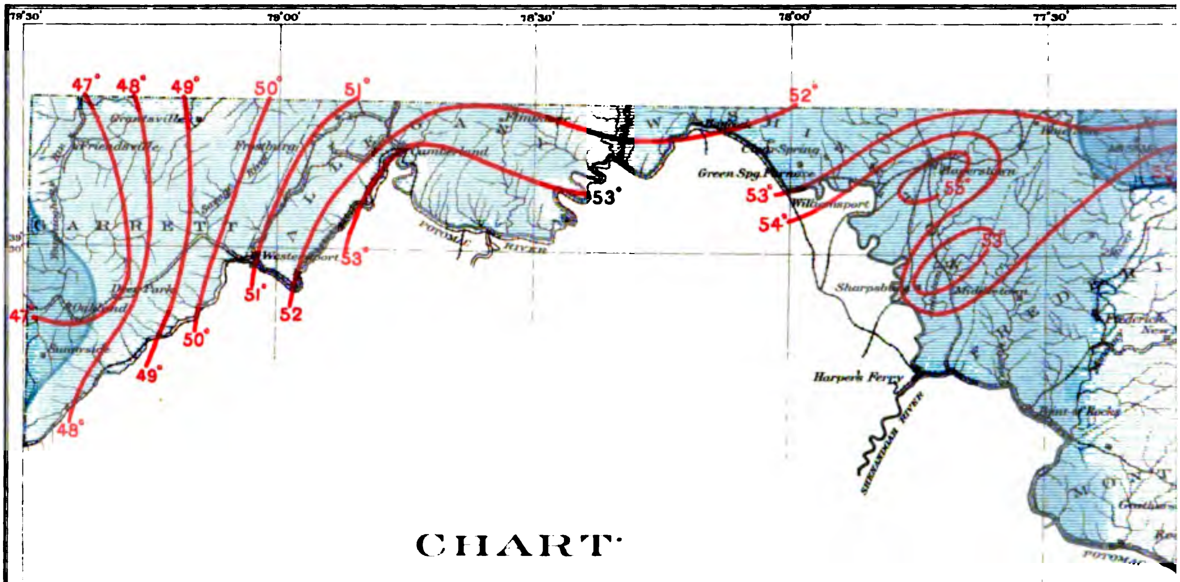
70° 70°

PRECIPITATION IN INCHES

1-2 2-3 3-4 4-5



A. Hoen & Co. Lith. Baltimore.



CHART

SHOWING THE

NORMAL TEMPERATURE AND PRECIPITATION

FOR

MARYLAND

INCLUDING

DELAWARE AND THE DISTRICT OF COLUMBIA

OCTOBER

SCALE

1:1,250,000. 20 Miles = 1 Inch

0 5 10 20 40 60

MARYLAND STATE WEATHER SERVICE

WM. B. CLARK, DIRECTOR

F. J. WALZ, METEOROLOGIST

1899

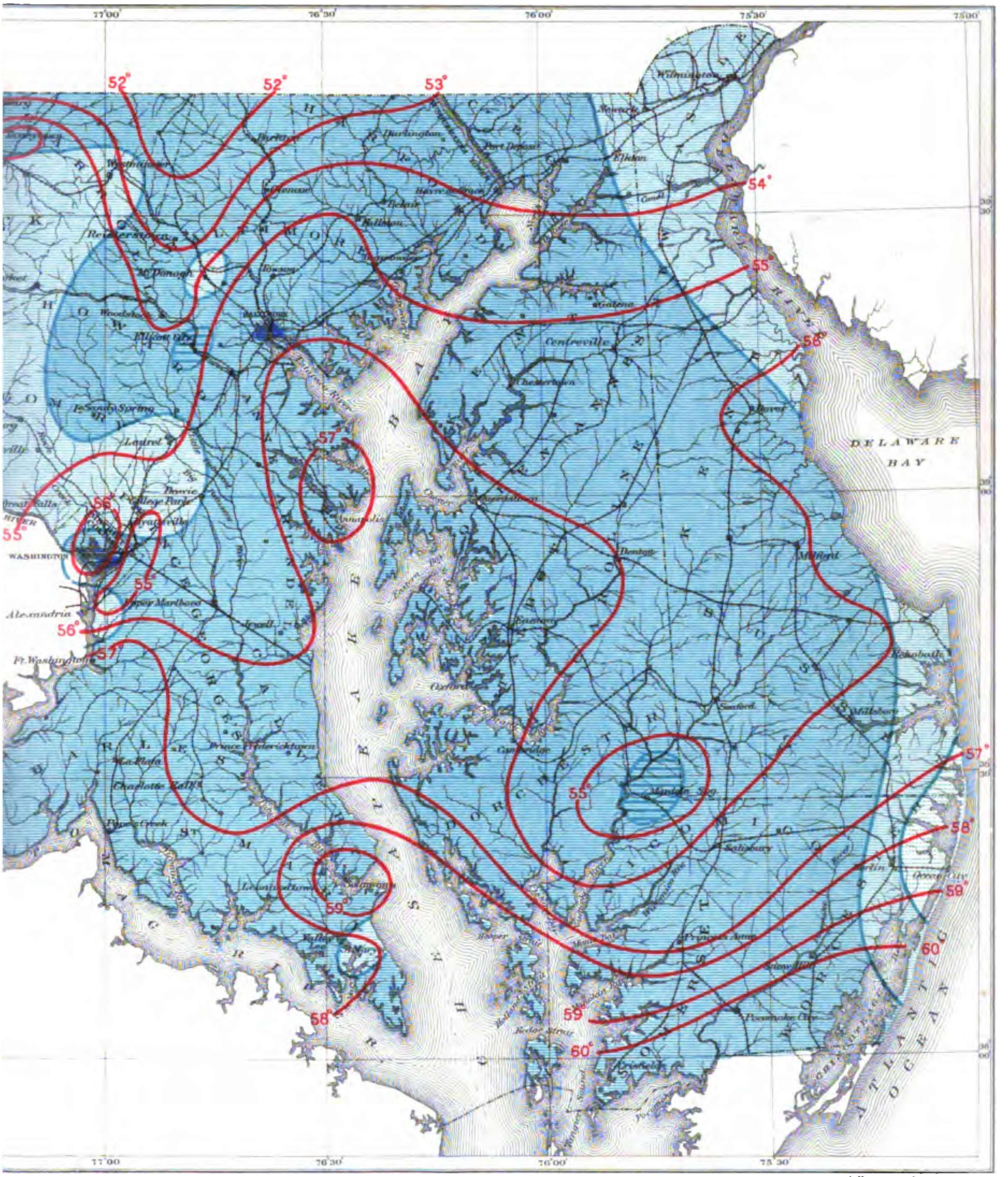
LEGEND

TEMPERATURE IN DEGREES FAHRENHEIT

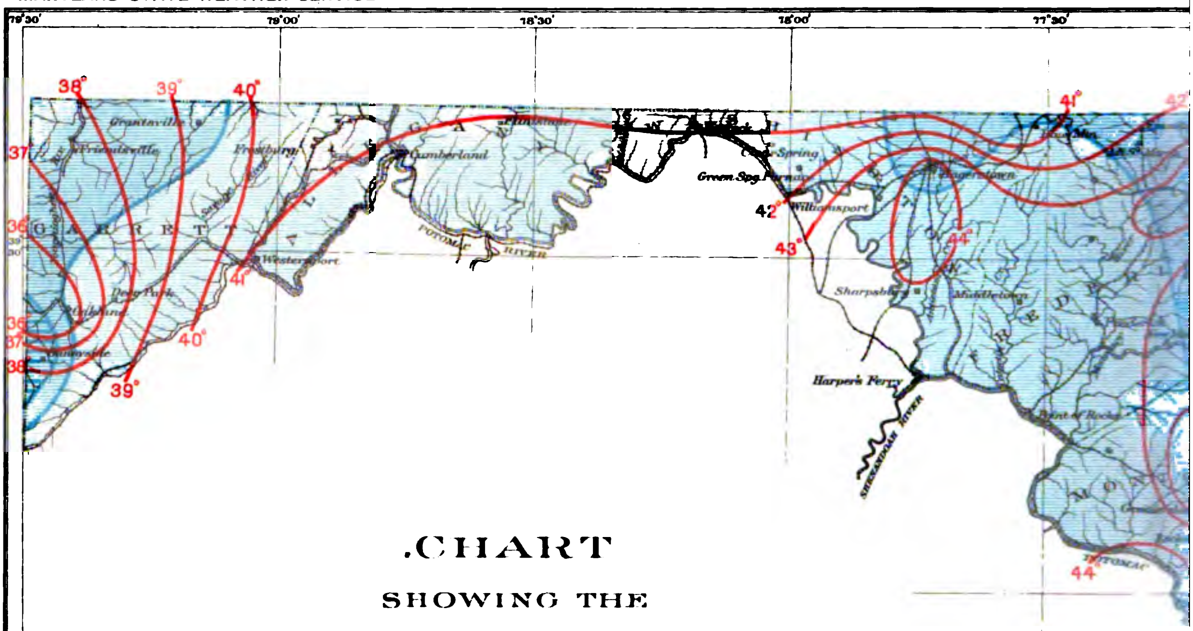
60° ——— 60°

PRECIPITATION IN INCHES

1-2	2-3	3-4	4-5



A. Hoen & Co. Lith. Baltimore.



.CHART

SHOWING THE

NORMAL TEMPERATURE AND PRECIPITATION

FOR

MARYLAND

INCLUDING

DELAWARE AND THE DISTRICT OF COLUMBIA

NOVEMBER

SCALE

1: 1,250,000. 20 Miles = 1 Inch

0 5 10 20 40 60

MARYLAND STATE WEATHER SERVICE

WM. B. CLARK, DIRECTOR

F. J. WALZ, METEOROLOGIST

1899

LEGEND

TEMPERATURE IN DEGREES FAHRENHEIT

50° ——— 50°

PRECIPITATION IN INCHES

2-3 3-4 4-5

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MARYLAND STATE WEATHER SERVICE

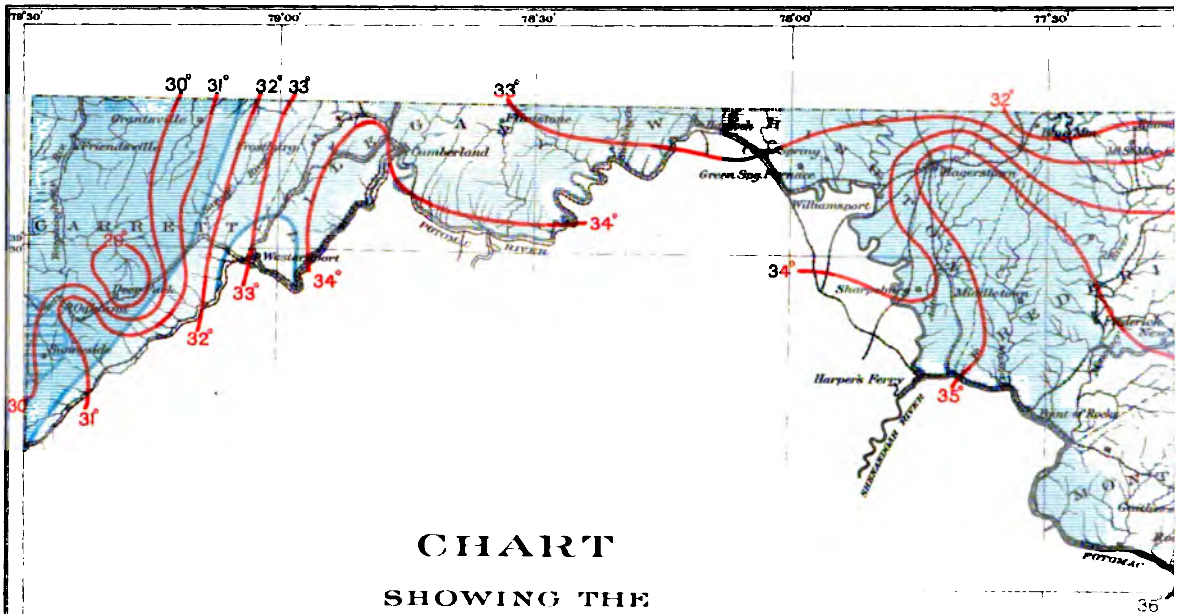


CHART
SHOWING THE
NORMAL TEMPERATURE AND PRECIPITATION
FOR
MARYLAND
INCLUDING
DELAWARE AND THE DISTRICT OF COLUMBIA
DECEMBER

SCALE

1:1,250,000. 20 Miles = 1 Inch

0 5 10 20 40 60

MARYLAND STATE WEATHER SERVICE

WM. B. CLARK, DIRECTOR

F. J. WALZ, METEOROLOGIST

1899

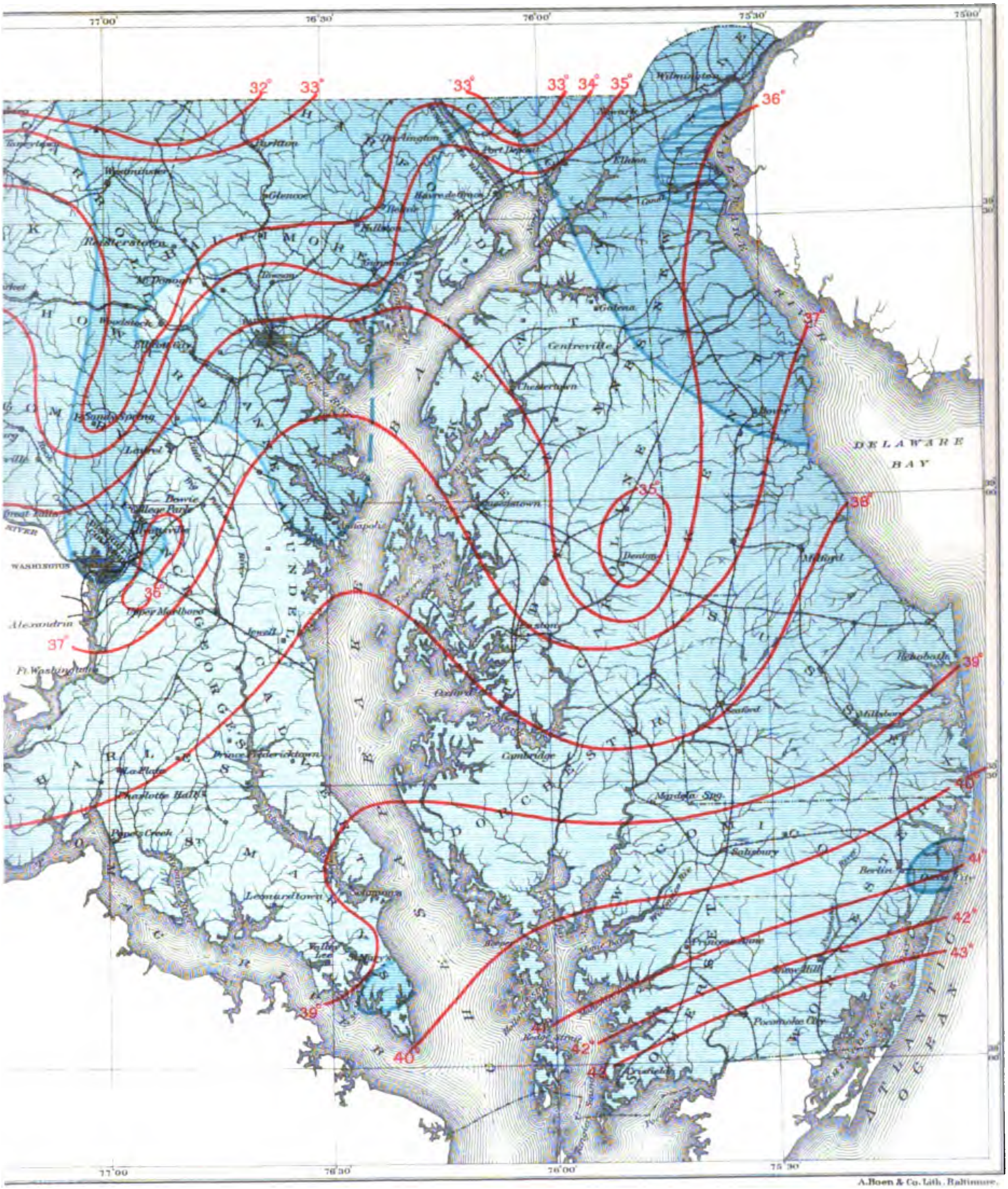
LEGEND

TEMPERATURE IN DEGREES FAHRENHEIT

35° ——— 35°

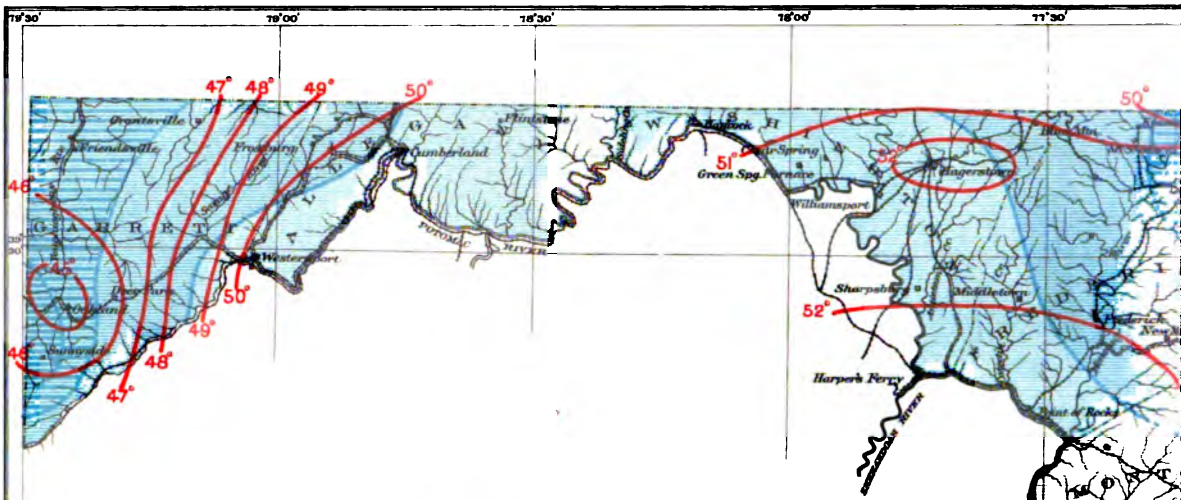
PRECIPITATION IN INCHES

1-2	2-3	3-4	4-5



A. Hoen & Co. Lith. Baltimore.

MARYLAND STATE WEATHER SERVICE



CHART

SHOWING THE

NORMAL TEMPERATURE AND PRECIPITATION

FOR

MARYLAND

INCLUDING

DELAWARE AND THE DISTRICT OF COLUMBIA

SPRING

SCALE

1:1,250,000. 20 Miles = 1 Inch

0 5 10 20 40 60

MARYLAND STATE WEATHER SERVICE

WM. B. CLARK, DIRECTOR

F. J. WALZ, METEOROLOGIST

1899

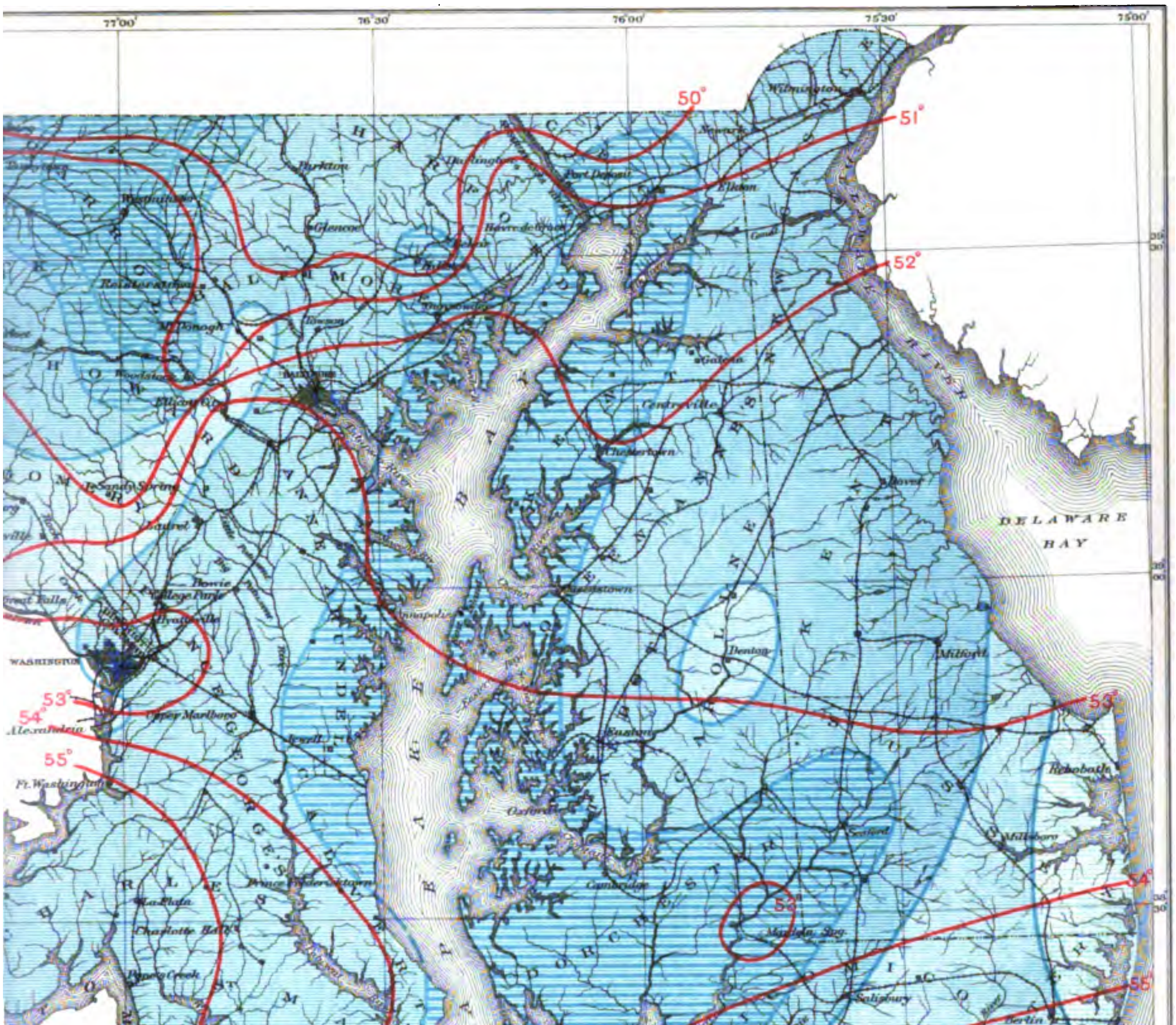
LEGEND

TEMPERATURE IN DEGREES FAHRENHEIT

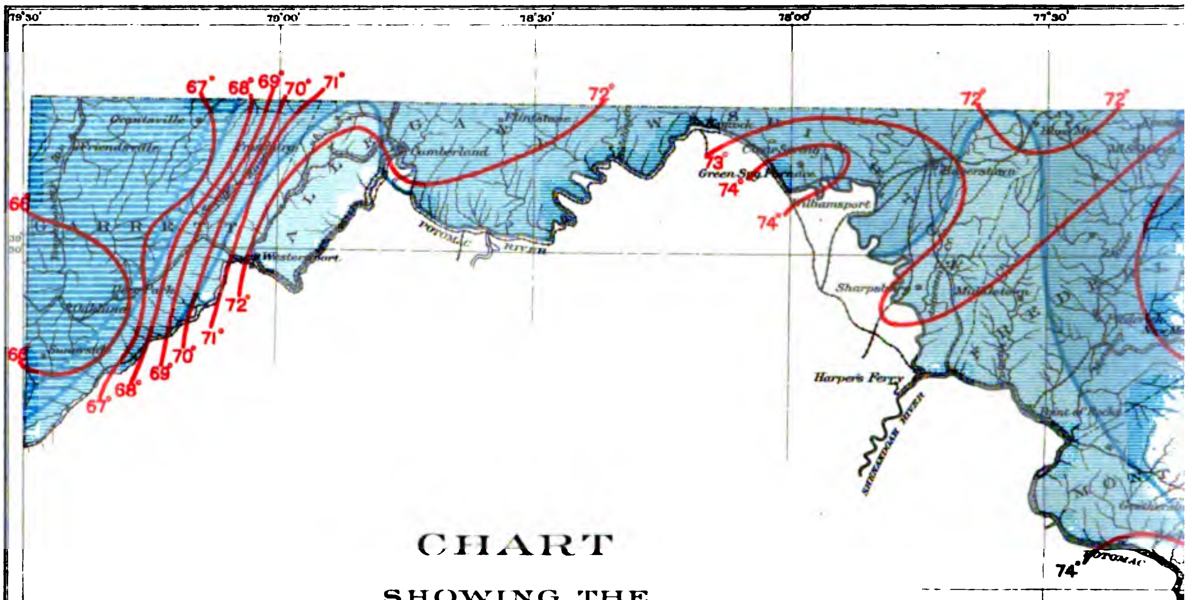
50° 50°

PRECIPITATION IN INCHES

6-8 8-10 10-12 12-14 14-16



A. Hoen & Co. Lith. Baltimore.



CHART

SHOWING THE

NORMAL TEMPERATURE AND PRECIPITATION

FOR

MARYLAND

INCLUDING

DELAWARE AND THE DISTRICT OF COLUMBIA

SUMMER

SCALE

1:1,250,000. 20 Miles = 1 Inch

0 5 10 20 40 60

MARYLAND STATE WEATHER SERVICE

WM. B. CLARK, DIRECTOR

F. J. WALZ, METEOROLOGIST

1899

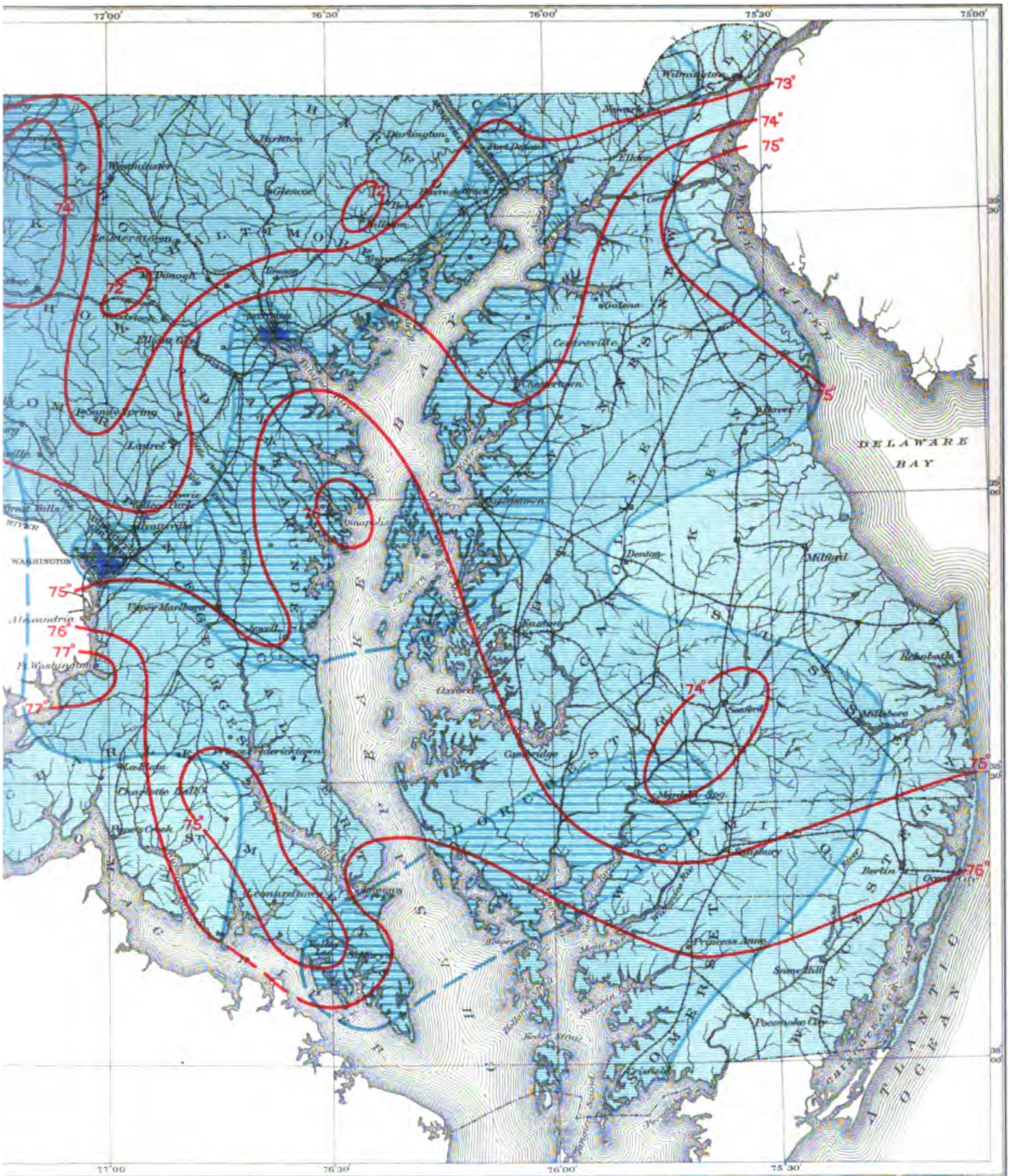
LEGEND

TEMPERATURE IN DEGREES FAHRENHEIT

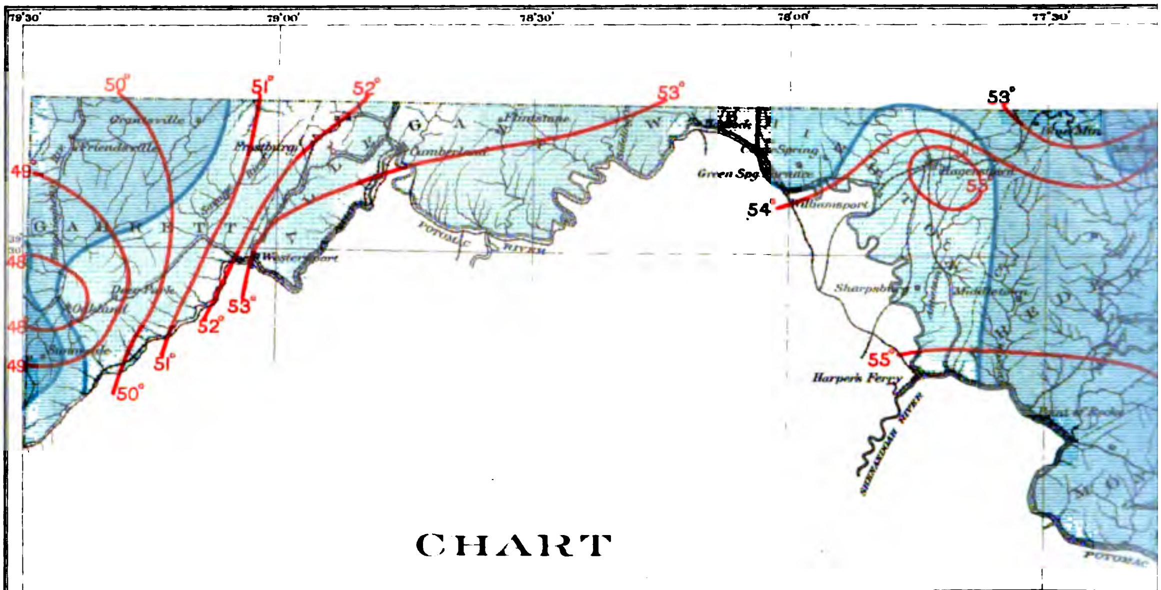
70° —— 70°

PRECIPITATION IN INCHES

8-10 10-12 12-14 14-16



A. Hoen & Co. Lith. Baltimore.



CHART

SHOWING THE

NORMAL TEMPERATURE AND PRECIPITATION

FOR

MARYLAND

INCLUDING

DELAWARE AND THE DISTRICT OF COLUMBIA

AUTUMN

SCALE

1:1,250,000. 20 Miles = 1 Inch

0 5 10 20 40 60

MARYLAND STATE WEATHER SERVICE

WM. B. CLARK, DIRECTOR

F. J. WALZ, METEOROLOGIST

1899

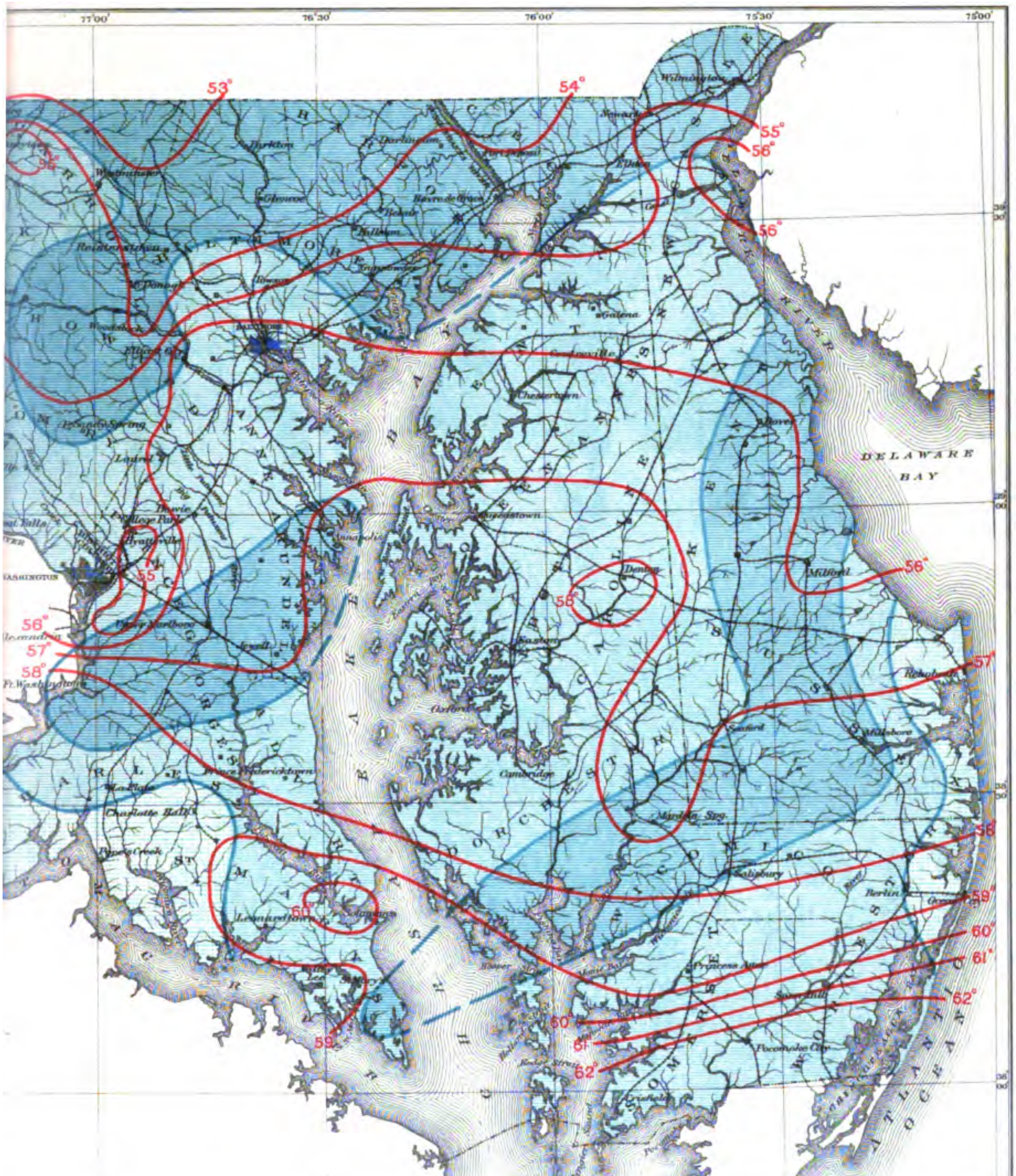
LEGEND

TEMPERATURE IN DEGREES FAHRENHEIT

55° 55°

PRECIPITATION IN INCHES

6-8 8-10 10-12



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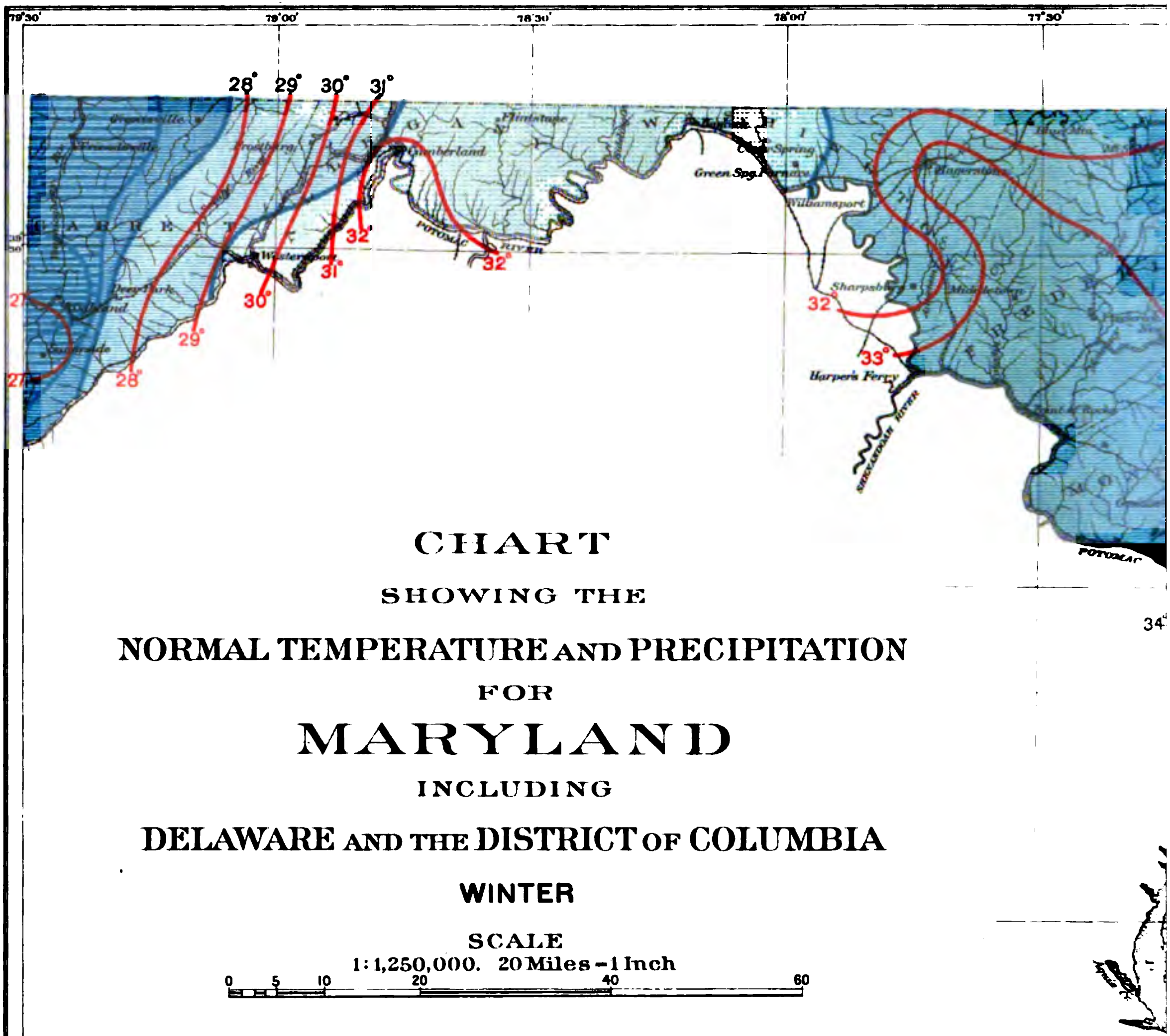
MARYLAND STATE WEATHER SERVICE



CHART

SHOWING THE

NORMAL TEMPERATURE AND PRECIPITATION

FOR

MARYLAND

INCLUDING

DELAWARE AND THE DISTRICT OF COLUMBIA

WINTER

SCALE

1: 1,250,000. 20 Miles = 1 Inch

0 5 10 20 40 60

MARYLAND STATE WEATHER SERVICE

WM. B. CLARK, DIRECTOR

F. J. WALZ, METEOROLOGIST

1899

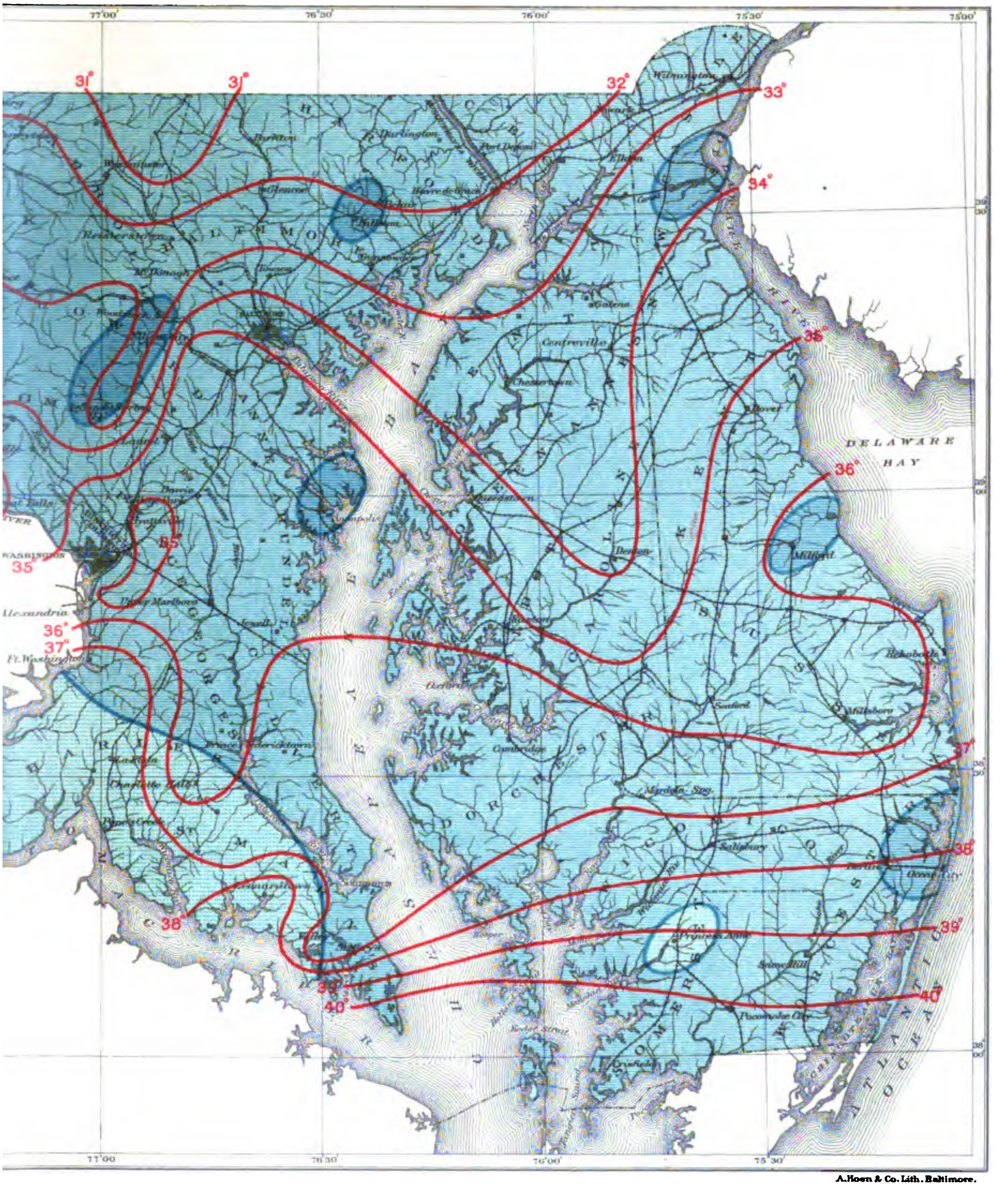
LEGEND

TEMPERATURE IN DEGREES FAHRENHEIT

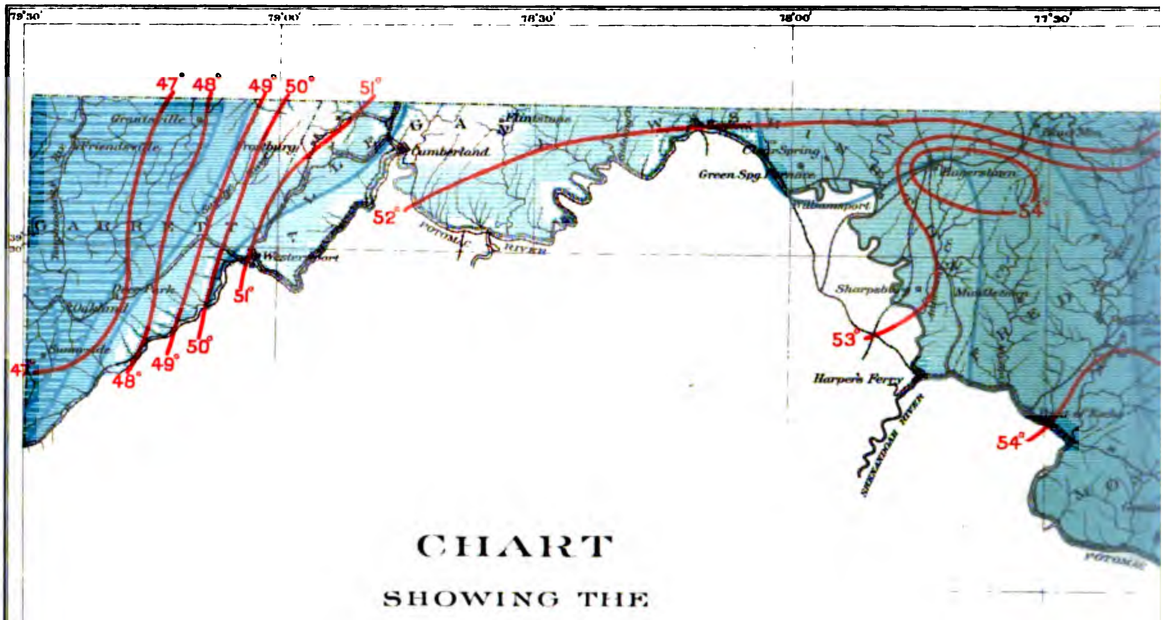
35° —— 35°

PRECIPITATION IN INCHES

6-8 8-10 10-12 12-14 14-16



A. Hoen & Co. Lith. Baltimore.



CHART

SHOWING THE

NORMAL TEMPERATURE AND PRECIPITATION

FOR

MARYLAND

INCLUDING

DELAWARE AND THE DISTRICT OF COLUMBIA

YEAR

SCALE

1:1,250,000. 20 Miles = 1 Inch

0 5 10 20 40 60

MARYLAND STATE WEATHER SERVICE

WM. B. CLARK, DIRECTOR

F. J. WALZ, METEOROLOGIST

1899

LEGEND

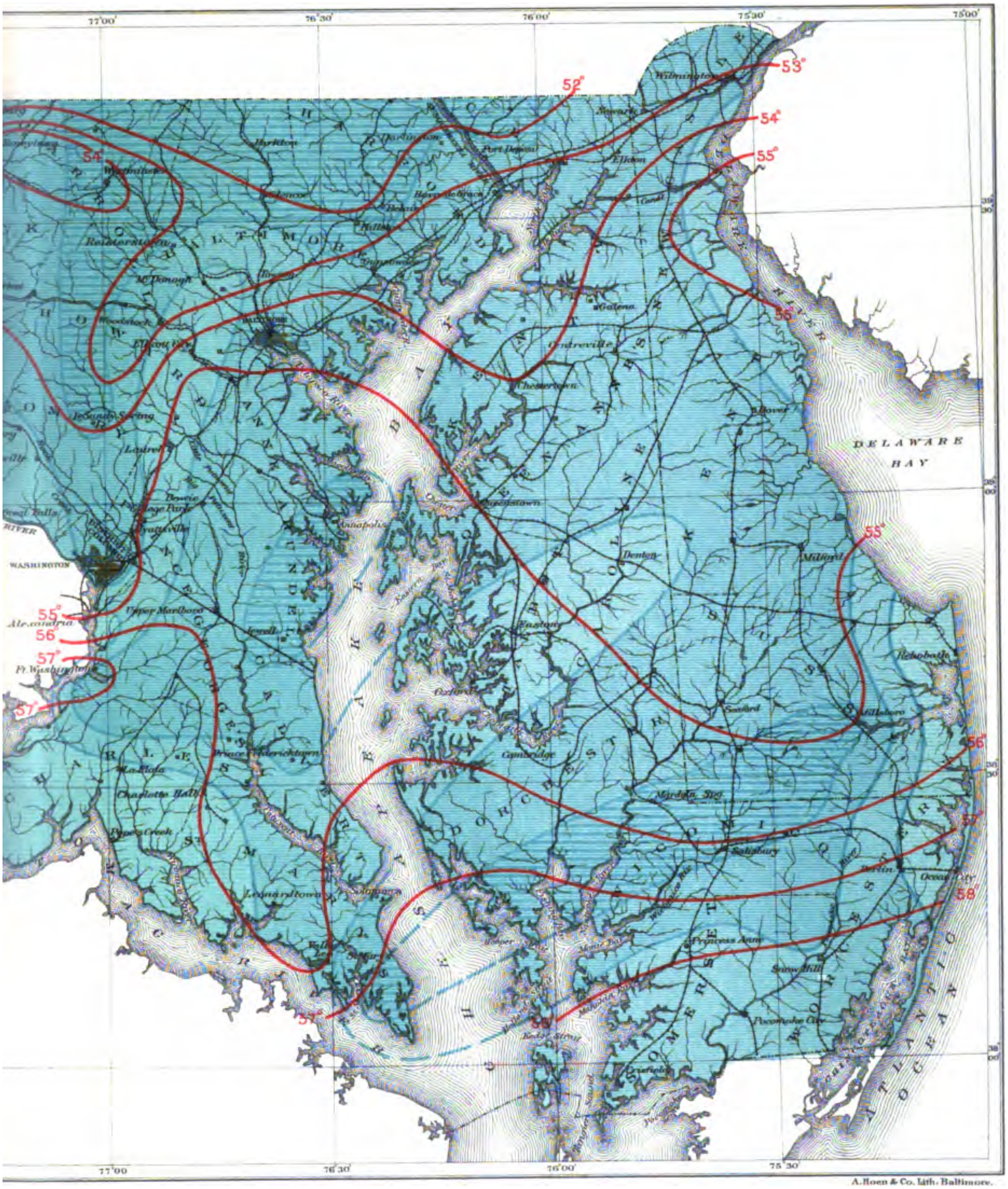
TEMPERATURE IN DEGREES FAHRENHEIT

55° ——— 55°

PRECIPITATION IN INCHES

30-35 | 35-40 | 40-45 | 45-50 | 50-55

VOLUME I. PLATE LIV.



A. Hoen & Co. Lith. Baltimore.